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Emergency Packaged Water Distribution System

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Emergency Packaged Water Distribution System

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Abstract

This report, prepared for the Puerto Rican Aqueduct and Sewer Authority, documents the feasibility of implementing an emergency packaged water distribution system throughout Puerto Rico. The project analyzed all aspects of various bottled and bagged water packaging methods, including a thorough cost analysis of these methods and customer reactions to the proposed packaging types. Detailed analysis of federal regulations governing packaged water and packaging facilities were also included. A roadmap has been provided for the implementation of a packaged water system and recommendations on the use of such a system to supplement their current emergency system.

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Executive Summary

As one of the most complex water suppliers in the northern hemisphere, the Puerto Rico Aqueduct and Sewer Authority (PRASA) has a responsibility to a large number of customers. This responsibility is complicated by infrastructure problems such as broken water pipes that arise from mechanical problems and natural disasters. When these infrastructure problems occur, PRASA implements an emergency water delivery system consisting of potable water trucks that distributes water to the affected areas. However, as PRASA continues to raise its water rates, customers expect increased quality of service. PRASA believes that this increased quality of service may be accomplished in part by the addition of packaged water to the current emergency system of potable water trucks.

Emergency water systems involving packaged water are common to countries throughout the world. When water systems fail to operate it is common practice to distribute water in the form of bottles or bags. Within the United States, the military distributes bagged water during times of emergency, and organizations such as the Federal Emergency Management Agency (FEMA) distribute bottled water to affected areas during emergencies. PRASA hopes to replicate the successes of these organizations by adding a form of packaged water to its current emergency system. PRASA currently owns four non-operating machines that produce bagged water, and they are interested in using these machines along with the purchase of more machinery to offer aid in future emergency situations.

The major goal of this project was to create a distribution plan for the addition of packaged water into PRASA's current emergency system of potable water trucks. Our

project created a general distribution plan that could be applied to both bagged and bottled water that would supplement potable water trucks in providing emergency water supplies to troubled communities. The project also looked into the applicable federal regulations, necessities, and costs of an operational water packaging system. Our final goal was to gain further insight into the social aspect of our project by gauging the public's perception on the addition of packaged water to the current emergency system of potable water trucks.

To accomplish these goals, the team first analyzed the operational standards of bagged and bottled water machinery. This involved identifying the detailed Federal Regulations of the FDA, EPA, and the Puerto Rico Department of Health that are required to maintain safe operation of packaged water machines. The operational standards were determined through the study of Federal codes and regulations, and by contacting professionals in the packaged water industry. By analyzing all of the regulations pertaining to packaged water, we were able to create several checklists of the major regulations. Representatives from both the FDA and the Puerto Rico Department of Health validated the accuracy of these checklists.

The creation of a distribution system for packaged water required an industrial engineering analysis to determine the production processes of packaged water, possible distribution points across the island, and modes of external packaging for the water. Examination of the production processes of packaged water machines, including a visit to a bottled water facility, enabled our team to create a set of guidelines for the efficient production of packaged water. Possible distribution points were determined by examinations of deficiency reports to locate areas with inadequate service. Finally, we determined the best methods of external packaging for both bottled and bagged water by visiting and contacting companies with experience in external packaging.

Cost analysis was performed to test the feasibility of the distribution of packaged water. Our team determined the operational costs of both the bagged and bottled water systems. Our results show the prices for initial production values of both bottled water and bagged water. What we found is that the majority of the cost for both bagged and bottled systems is the cost of external packaging. Our results showed that the production of bottled water is roughly three times the cost of similar bagged water systems.

To accomplish our social goal, we conducted a convenience sampling survey of a small number of PRASA's customers. The convenience sampling survey was administered at two locations, San Juan and Ponce, where we were able to obtain a total of 108 responses from PRASA's customer base. We explained the idea of an emergency distribution system involving packaged water, and allowed the individuals being surveyed to hold a bag of water. From our survey, 52% of the individuals interviewed believed that using packaged water was a good idea. However, the public was concerned about the use of bagged water. The results showed that 22% of the public didn't know how to react to the bags because they were unfamiliar with bagged water.

Our results led us to the following list of recommendations for the future of this packaged water system:

FDA Regulations - Comply with the Federal Regulations as failure to meet these regulations can lead to heavy penalties and fines. We suggest avoiding further filtration because it is not required by law.

Distribution – Initial water production facilities should be located at the Sergio Cuevas filtration plant, with future facilities located at the Fajardo Nueva, Guaynabo, Ponce Nueva, and Miradero filtration plants. These filtration plants are reliable and have the ability to operate during emergencies such as power outages or hurricanes. Storage facilities are recommended for difficult to access areas such as the mountainous regions, Vieques, and Culebra. However, packaged water should not be stored for more than the industry standard shelf life of two years.

Usage – We recommend that the bagged water system be used initially because the machinery has already been purchased. If the production is to be increased we recommend purchasing water bottling machines because they are more socially accepted and will allow for easier distribution among PRASA's clients.

Public Opinion – The public needs education on the proper use and safety concerns involving bags of water. We recommend that the bagged water product be marketed to the public to build awareness and ensure that residents take full advantage of the packaged water system in the event of an emergency. This can be done by handing out samples of the bags of water at social events, as well as through newspaper, magazine advertisements, and informational pamphlets within monthly water bills.

Our detailed recommendations outline a plan for the addition of packaged water to the current emergency distribution plan of potable water trucks. We believe that if our recommendations are followed, it will improve the efficiency of the current water distribution system, and it will better prepare PRASA for emergency situations.

1. Introduction

With the disasters of Hurricane Katrina and the South Asian tsunami still looming large in everyone's mind, the necessity for an emergency water distribution plan is essential for survival. Water is one of the most vital elements on the planet, and its loss can be devastating to any human population. People need access to a clean water supply, especially during times of emergency. With almost two-thirds of the earth covered by water, it is difficult to understand how a shortage of clean water could exist. However, only one percent of the water in the world can be consumed, and even less is considered to be potable. Most countries have difficulties supplying potable water to their people during emergency situations. These situations are made worse by natural disasters, technical problems, and contamination. The problem facing many countries is that they are poorly prepared for these emergency situations.

In some cases, such as the Commonwealth of Puerto Rico, the formation of an ideal emergency water distribution plan is in the beginning stages but is far from complete. The Puerto Rico Aqueduct and Sewer Authority (PRASA) is responsible for ensuring that its customers have access to a clean water supply during service interruptions due to natural disasters or technical problems. They currently use a system of tanker trucks to distribute emergency water supplies. This system of trucks has been partially successful in past situations but is not able to provide adequate, efficient coverage to PRASA's entire customer base. PRASA has decided to improve the current system by implementing an additional emergency system involving the distribution of packaged water. While the idea of supplying packaged water to customers during service interruptions sounds practical, it comes with its own set of logistical problems.

Packaged water is a common form of water relief during times of emergency. For the past several years, the Federal Emergency Management Agency (FEMA) and cities such as Seattle have distributed packaged water to communities during emergencies. However, the disaster of Hurricane Katrina shows that even organizations dedicated to emergency relief are not prepared for every situation. Unfortunately, Puerto Rico faces emergency service interruptions quite frequently, and it is common for portions of the island to receive no emergency water supplies. Two years ago, one private corporation attempted to replicate the past success of FEMA and other organizations by creating an emergency packaged water distribution system in Puerto Rico. However, the private corporation's efforts were not successful. The private corporation purchased four water packaging machines but never solved the major problems associated with a distribution plan.

PRASA plans to build upon the distribution plan started by the private corporation, but faces two major problems. The first problem involves the production processes associated with packaged water. Proper research into the water industry is required to create a standard of production that can be applied to make an efficient system for the safe packaging of water in Puerto Rico. The second problem is creating an emergency distribution plan that is able to provide water to all of PRASA's customers in a timely and efficient manner.

The first goal of this project was to develop a plan for the effective distribution of packaged water in the Commonwealth of Puerto Rico during service interruptions. This plan entailed the production, storage and transportation of packaged water to supplement the current system of tanker trucks in a manner generalized enough to apply to both bagged and bottled water machinery. The project also formulated a standard of production through the study of Federal laws and regulations, and by an understanding of the modern packaged water industry. Our final goal was to determine the consumer reaction to this extra emergency help. This was accomplished through a survey of over 100 of PRASA's customers. Based on the results we acquired, our final product is a series of recommendations for the implementation of an emergency distribution system for packaged water, suitable for Puerto Rico.

2. Background

With recent rises in water prices, PRASA is feeling the public pressure to increase its quality of service, and this has led to the goal of creating the packaged water distribution system to supplement its current emergency plan. In order to understand how this goal may be accomplished, knowledge of PRASA's current emergency plan is required, along with detailed knowledge of packaged water systems in general. This chapter will discuss issues relevant to our project, such as current emergency water distribution plans implemented by PRASA, along with similar emergency water plans in place across the United States. Because PRASA hopes to add packaged water to its emergency water distribution system, it is also necessary to understand how Federal regulations and requirements will apply to packaged water. Finally, knowledge of water production facilities is required, so the chapter will conclude by familiarizing the reader with a number of different water packaging methods.

2.1 Emergency Water Distribution Systems in Place

When the delivery of potable water through the municipal distribution system has been disrupted, an emergency plan must be set in place to ensure the health and safety of everyone. Generally, an emergency distribution plan consists of a clean source of water, as well as a packaging and distribution system.

Clean water can be stored solely for use during emergencies, but proper practices need to be carried out. To ensure emergency sources are ready to use, systems should have a maintenance strategy, make needed repairs in a timely manner, and keep good records of inspections (FEMA, 1992). The strategy should include:

Testing – The source water should be periodically tested for bacteria, nitrates and other contaminants to protect water quality.

Inspecting – Operational controls should be inspected at least quarterly to keep components in good working order. Also, electrical connections and components should be checked for corrosion, as well as sanitary seals, vents and other hardware.

Operating – The pump(s) should be periodically operated to ensure the source is ready to supply the clean water. It is also important to check and exercise all valves and controls.

Not only is it important for the quality of water stored to be up to standards, it is also important to have an adequate supply. In emergency cases, the recommended amount of water to be supplied per person per day is one gallon.

In order to deliver the necessary amount of water to people in need, municipal water distribution systems are required to develop emergency plans in case of service interruptions. Each organization has a unique system based on its needs and available assets. While these organizations follow these requirements above, there are many different systems available for the distribution of emergency water.

2.1.1 Massachusetts Water Resource Authority

The Massachusetts Water and Resource Authority (MWRA) is regarded as having a complete and reliable water distribution system. In the case of water emergencies, the MWRA uses a method that is built into the infrastructure (D. Gilmartin, personal interview, February 3, 2006). The MWRA has quite a different infrastructure and environment from that of PRASA. The MWRA has two main reservoirs as well as two storage reservoirs. One of the main reservoirs is 412 billion gallons and the other is 63 billion gallons. All water for the city of Boston starts in the Quabbin Reservoir and then goes to the Wachusett Reservoir through a main pipeline.

If the main pipeline breaks, water can still be siphoned off from the Wachusett reservoir until the problem with the main pipeline is resolved. After water leaves the Wachusett reservoir, it travels through two aqueducts into Clinton and there is one open channel. Behind all of these systems are four backup reservoirs.

As a result of all of these systems, there are enough redundant systems where MWRA can have water delivered to all its customers in case of a major problem with the main reservoirs. In a worst-case scenario, however, the MWRA may have to place a boiled water notice, which would require that customers boil their water before using it.

This system is quite different from the infrastructure that PRASA has developed. PRASA has multiple dams, reservoirs, filtrations plants, and pump stations that independently service different regions of the island (Adamaris Quinones, personal communication, March 29 2006). Given this unique infrastructure, PRASA would be unable to implement an emergency water distribution plan similar to the MWRA. However, the MWRA may be considered a model for water distribution and management, as it is a point of comparison for other water distribution systems due to its strong infrastructure and highly trained staff.

In an effort to move forward and improve their distribution system PRASA is implementing a Capital Improvement Plan (CIP). Over the next five years they hope to improve their infrastructure by simplifying their treatment plants and constructing four new reservoirs throughout the island. By investing over 3 billion dollars in their system they hope to reduce their areas of deficiencies and create a reliable system much like the MWRA.

2.1.2 Seattle's Bagged Water Distribution

. An example of an emergency packaged water distribution system is one belonging to the Seattle Public Utilities (SPU) of Seattle, WA ("WaterWorld," 2006). In a plan to ensure that the 1.3 million customers will have an adequate, reliable emergency water supply, the city of Seattle set up an Emergency Drinking Water Provisioning System that can deliver up to 612,000 gallons of water a day to six distribution sites around the city.

In an emergency, a potable water distribution system, consisting of a generator, a tent, a table, chairs, a 3,500 gallon water storage unit, and the dispensing equipment, is dispatched to a designated distribution site. The water storage unit is connected to a pumping system that dispenses water into individual six-quart bags. The bags were designed with a special puncture seal that keeps the bags sterile until they are filled and ensures that the consumers do not reuse unhygienic containers. The bags are quickly filled in 25 seconds, capped, and then sent home with the local resident.

Not only does this system make it easy to transport water, but it also takes minimal staffing to operate because the bags are filled and packaged on site. Only about six SPU staff members are required to operate the system at the distribution site. This emergency packaged water system implemented by SPU seems to be an ideal way to distribute safe, potable water to a large number of people, with a limited workforce.

2.1.3 International Bottled Water Association

While not many emergency water distribution systems exist that utilize bottled water, the International Bottled Water Association (IBWA) is currently in the process of making a distribution plan that will be applicable to any situation. The IBWA is the trade association representing bottled water. It represents a group of distributors, suppliers, and bottlers who have come together to form a group that will ensure high quality water is delivered to its customers.

The IBWA requires that all members register information on a central data base. This information includes all pertinent data relating to the reaction capabilities of the member in an emergency. This includes reaction time, the amount of water they could contribute, and any other logistics that could be involved. Once all data have been acquired, the information is assembled and sent to the government, FEMA, and other emergency relief organizations in order to provide them with the resources necessary in the case of an emergency. Instead of bringing water from a centralized point, the emergency relief organizations can contact facilities local to the affected area in order to better serve society as a whole (Stephen Kay, personal communication, March 16, 2006).

2.2 FDA Regulations and Restrictions

Members of the IBWA have their own model code to follow, but on a larger scale the entire bottled water industry falls under the jurisdiction of the United States Food and Drug Administration (FDA). Unlike tap water, bottled water is not regulated by the Environmental Protection Agency (EPA). The FDA regulates all bottled water and water bottling facilities in the United States and Puerto Rico. The FDA has jurisdiction over bottled water because once water is taken and bottled for distribution it is counted as a food product. Not only is the water itself regulated, but so are the facilities, the bottles to be used, and the labels for the bottles. The FDA has many sections in the Code of Federal Regulations that cover each topic separately and explain all situations in great detail. Further regulations can be added by the state governments; however none are currently in place in Puerto Rico.

2.3 PRASA's Current Emergency Distribution System

When water mains break or there is a hurricane that results in a water outage for an extended period of time, PRASA has to provide water to its customers (Mayra Encarnacion, personal communication, March 15, 2006). Customers call PRASA's emergency center to report all outages and these are compiled in two daily reports. These reports are necessary so all outages can be addressed and fixed in a timely manner. While customers in a certain area are not receiving water PRASA will provide water to the public in another way. PRASA contracts through multiple third party companies for a number of potable water trucks. These trucks can be filled with water directly from designated fill stations and are distributed throughout the affected areas.

Figure 1 - Water Truck Being Filled

Figure 1, above, shows a potable water truck being filled from the Sergio Cuevas filtration plant. Once the truck is full, the driver is required to bring a sample of the water from the truck to an office located at the filling station. The water is then tested for appropriate chlorine, turbidity, and pH levels (Mabel Sanchez, personal communication, March 31, 2006). The testing equipment used is shown in Figure 2. The test information is documented as well as the destination of the water and information about the truck driver and truck.

Figure 2 - Water Testing Equipment

PRASA uses these trucks to provide water for both industrial and individual clients. Industrial clients fall into two distinct groups: public agencies and private agencies. Public agencies, such as public hospitals, schools, refuge centers, and fire departments, always have water supplied to them in case of an emergency free of charge. Private organizations however have to pay extra for the water. They purchase vouchers in advance for the amount of water they estimate that they will need if there is a service interruption. Depending on how many vouchers they wish to use they can have a specific number of trucks assigned to them throughout the outage. The trucks are required to bring a constant flow of water to the facility until the emergency is over.

The individual clients, on the other hand, are a completely different issue. In order for individuals to obtain water from the potable water trucks, the trucks are placed in centrally located positions near the affected areas. Usually one person per household will bring his or her own container, such as five gallon water containers, and fill them directly out of the truck.

Figure 3, shown below, displays community members waiting in line to receive water from a potable water truck. This method of parking the trucks in one spot is somewhat problematic. There have been times when trucks were detained while distributing water due to large masses of people swarming around the trucks. Police escorts are unfortunately not available for every water truck and the drivers are not able to handle crowd control on their own. For these reasons, PRASA would like to implement a different system for communities.

Figure 3 - Potable Water Truck (Caribbean District Science Plan 1999, 2005)

2.4 Packaging Machines

PRASA is looking into packaging its water in an effort to improve Puerto Rico's emergency water distribution system. A system of distributing packaged water aimed towards residential customers would supplement the emergency system already in place. With packaged water, distribution in emergency cases would be faster, easier, and more convenient for the customer. People would not have to provide their own containers as they do now, and they would not have to wait while their containers are filled. Furthermore, the quality of the potable water is easily ensured when the water is provided in sterile, sealed packages. With potable water trucks there is no way to guarantee that the containers people are bringing with them are clean and sanitary.

There are a number of machines that have the capability to package water in different ways. The most common packaging for water is bottles, but plastic bags are also an option and are common in many South American countries. Whether water comes in bags or bottles the process of packaging water involves many of the same steps. PRASA hopes to begin packaging its water in plastic bags and then at some point move to packaging water in bottles, the method most commonly used in the United States.

2.4.1 Argenpack Bagged Water

In 2003, while PRASA was being managed by the private corporation Ondeo, four Argenpack 2500® water packaging machines were purchased for $77,700 (Mabel Sanchez, personal communication, March 31, 2006). They were purchased to provide drinking water to customers during emergency situations or other service interruptions. Each Argenpack machine is fast and efficient producing approximately 2,500 – one liter bags of water per hour (pictured in Figure 4 and Figure 5). They also take up minimal space, with each machine having a height of 7.2 feet, a width of 1.5 feet, and a depth of

2.9 feet. To ensure sterile and safe packages, each machine is complete with an ultraviolet lamp that sterilizes the plastic film before the bags are filled and sealed. The Argenpack machines are also easily managed and do not require much training on the operator's part. With all these qualities and a suitable plan of action for the distribution of the bagged water, the Argenpack 2500® machines could be very useful in ensuring that all of PRASA's customers are always provided with potable water.

Figure 4 - Argenpack 2500®

Figure 5 - One liter bags produced

2.4.2 Bottled Water

With the possibility that Puerto Ricans are completely resistant to receiving water in a bag, it may be necessary for PRASA to purchase bottling machines. Bottling machines operate slightly different from the bagging machine shown above. There are more processes in the bottling of water which we saw by researching information on a

VP50 filler machine from Venus Packaging. (Venus Packing Machines PVT. LTD, 2006).

A picture of this device is shown below in Figure 6. The bottles are loaded onto a conveyer where the bottles are positioned to be cleaned and filled. The bottles are cleaned inside the machine and then transferred to the filling point. In order to fill the bottles, the vent pipe filling principle is a generally accepted method to ensure accuracy and reducing waste. Now the bottles are ready to be capped.

Separately from the bottles, caps are kept in a reservoir where they are moved up a conveyer. Sometimes, depending on the machine, the caps may be oriented and sent through their cleansing procedure. The cleansing procedure can involve high power water jets and also UV light radiation of the caps. Once the caps are clean, they are transferred to a chute where they are placed on the bottles.

Once the bottles are capped they are exited out of the filling machine and a label will still need to be applied. This can be done manually with a heat shrink label that is placed around the bottle; the bottle is passed through a shrink tunnel to shrink the label firmly onto the bottle and the bottle of water is now completed. It only needs to be boxed and shipped to the appropriate storage location. Information on the production of the bottles for the bottling machines can be found in Appendix A.

Figure 6 - Venus Packaging VP50 (Venus Packaging Machines PVT. LTD., 2006)

The production capacity of both machines will need to be looked at as well. PRASA may need to purchase bottling machines for the sole fact that more packaged water will be necessary than the Argenpack machines can provide. These aspects and many others will help in choosing which system will work best for the island.

2.5 Summary

Whether it is through pipelines, potable water trucks, bags, or bottles, PRASA needs to supply water to its customers at all times. To attain an understanding of the means by which PRASA can accomplish this goal we investigated several reliable emergency water distribution systems in place in the United States, and the Federal laws that regulate all of them. With the information provided in this chapter we determined the necessary steps to attain the data required to complete our project.

3. Methodology

We aimed to provide PRASA with a suitable emergency packaged water distribution plan that would supplement the present system in place that uses potable water trucks. In order to accomplish our goal we identified four main objectives:

- To determine the public's views on emergency water distribution in Puerto Rico.
- To analyze and summarize all regulations that apply to a water packaging system.
- To assess the necessities of a water packaging system.
- To develop a cost analysis for the different water packaging systems.

3.1 General Population Survey

Many times the technical issues of a project are solved while the affected population is not consulted to determine their reactions to the proposed solution. In an attempt to predict how Puerto Ricans might react to the proposed emergency water distribution system and the potential use of bagged water, we used convenience sampling surveys to gather the needed information. Please refer to the survey in Appendix B for the questions that were asked. Convenience sampling has one very positive benefit, it can save time. With roughly five weeks to gather data, convenience sampling was the most practical method of surveying to get a general understanding of the public's opinion. Unfortunately, this sampling method does not produce a statistically valid representation of the whole island's population. However, it should provide a general idea of what some people in Puerto Rico think, since we tried to get opinions from as diverse a sample of people as possible.

We aimed to receive 100-150 responses. Because of our time limitations, we believed that this was a sufficient range to establish a basis for how the average Puerto Rican prepares for water outages and what they think of the current and proposed emergency water distribution system. The coverage area for the survey was limited to the San Juan and Ponce areas. We administered the survey mainly at the public shopping mall, Plaza Las Americas. Before we started to administer the survey, we gained permission from Plaza Las Americas General Manager, Franklin Domenech. In addition to the mall located in the northern part of the island, we conducted a survey using the same questions in the city of Ponce, located on the southern coast of the island. Content analysis was used to analyze the survey responses in order to determine a consensus about the Puerto Ricans' opinions on the current and proposed water management systems.

3.2 FDA Regulation Evaluation

The second objective involved analyzing and summarizing all the regulations that apply to a water packaging system, since any violations could result in monetary fines. The FDA mandates certain regulations concerning food products that the local health department then enforces. Most of the statutes concerning the bottling of water are located in the Code of Federal Regulations (CFR) created by the FDA. To get an understanding of what goes into water packaging facilities all of the regulations within the FDA pertaining to the emergency system were located and documented so PRASA could have them for their records.

We found all the regulations and put them in a checklist format so that when going over a facility everything that does not comply with the FDA's regulations can be noted. This will prepare PRASA for the development of a bottling facility and also for the health inspections to come.

After finding the regulations in the CFR and making sure they would be applicable to our project, we contacted the FDA to verify our findings. Representatives of the FDA in both Massachusetts and San Juan were contacted to make sure all of the regulations would indeed apply the way we understood them. As a last step we met with a representative of the Puerto Rican Department of Health to verify all of the information because while FDA creates the regulations, the health department enforces them.

3.3 Industrial Engineering Analysis

Industrial engineering is an important step in all design plans. In order to establish the needs of a water packaging system, an industrial engineering analysis was performed. Also, by applying an industrial engineering analysis we aimed to eliminate wastes of time, money, materials, energy, and other resources to determine the most efficient water packaging system.

In the first week of this project, we visited the Guaynabo filtration plant where the four Argenpack 2500® water packaging machines were located. On this trip we learned how the machines would operate and how many workers would be needed to operate these machines as well as what specific tasks they would need to perform. In addition, we also researched different bottling machines and configurations.

Since four machines have already been purchased and the prospect of purchasing additional machines also exists, it would be possible to place the machines at multiple positions on the island or to have all packaging operations at one central location. One concern with the positioning of the packaging facilities is that these locations should be near the areas that have frequent service deficiencies in order to serve those areas more easily. By looking through past reports of outages, we were able to find all the areas which frequently experienced water deficiencies.

Another concern with the location of the packaging facilities is that the packaging machines would need to be placed at filtration plants. We determined which filtration plants would be the most reliable during emergency situations, specifically when power outages occur. These filtration plants were chosen based on ideal characteristics, such as:

- **Backup Generators** - The loss of electrical power during an emergency situation would make any packaged water system non-operational. Backup generators would ensure that the loss of electricity would not affect the operation of a packaged water system. We looked for filtration plants with electrical generators, and we also determined whether the water source of the filtration plant had access to a generator.
- **Reliability** - The chosen filtration plants must be reliable in nature. If a plant fails to produce clean water on a regular basis, then any packaged water operations at the plant will also fail on a regular basis. The reliability of filtration plants was determined based on the knowledge of several PRASA employees.
- **Gravity Pipelines –** Gravity pipelines allow the filtration plant to receive water from its source, even when the source of that water has no electrical power. This would then avoid any complications that may arise from the existence of a power generator at the water source location.

From these analyses, we were able to determine how many packaging facilities are necessary for Puerto Rico and also the recommended location of these facilities.

3.4 Cost Analysis

During the development of our emergency distribution plan we needed to keep in mind the costs and benefits of the various alternatives. PRASA is a corporation, and just like every other corporation in the world, it is looking to make a profit. It was important to assess all of the cost factors in order to determine how the most cost-effective plan could be obtained. Several methods were used to help with our goal of creating a distribution plan for the packaged water system.

The first portion of the cost analysis details the purchasing of new bottled water equipment. The number of water packaging machines available to PRASA might be inadequate to provide coverage to all of the troubled areas. PRASA needed to know the costs of other machinery so multiple options would be available for their consideration. Cost analysis on this subject determined the most cost effective machines available to PRASA. To determine costs of machinery, several active individuals within the bottled water industry were contacted. These individuals provided knowledge on what types of machines and processes would be the most cost effective. The recommended machines were then studied and their production companies were contacted to determine their production output versus the costs of production and purchase.

Once the cost analysis on future machines was completed we then applied it to our general distribution plan that applies to all types of water packaging machines. All together we determined five important cost issues that needed to be analyzed. These cost issues are:

- Power Consumption
- Water Production

- Material (Packaging)
- Human resources
- Maintenance

The methods applied to each issue are detailed below:

The first two issues analyzed the cost of water production and energy use. To determine the cost of water production we contacted several plant managers to get data on the costs of water production. The energy costs for the water packing machines were disclosed based on an electricity rate that was determined by the Puerto Rican Energy and Power Authority (PREPA).

The packaging material for the packaged water was an important issue for our project. We contacted and visited the Flexible Packing Corporation, where we were able to meet with several individuals who had experience in the packaging of water products. From their advice we were then able to determine the least expensive packing that could be applied to our project.

Human resources were the most complex issue that we had to consider in our project. We considered several scenarios for the production plants to determine the personnel needed to run a water production facility from start to finish. Our group then contacted several employment officers within PRASA to determine the acceptable worker wages. With the knowledge of these wages, we were able to determine the scenarios that allowed production and distribution of packaged water to run at minimal cost.

The final issue that had to be considered was the maintenance of the machines. For the Argenpack 2500® machines that produce bagged water, the Argentinean company that created them was unable to be reached. The maintenance fees for these machines were estimated based on the initial cost of the machines and through communication with PRASA employees. As for the bottling machines, price quotes for their maintenance were acquired by contacting the respective manufacturing companies.

All of this information was compiled and analyzed to provide PRASA with the most cost effective plan. By also employing the methods of industrial engineering analysis, evaluating FDA regulations, and convenience sample surveying, we collected a sufficient amount of data for analysis. From these analyses we selected the most suitable emergency water distribution system for Puerto Rico.

4. Results and Analysis

To create our project recommendations, we analyzed the data collected using our methods. We first analyzed the general population survey to determine the public's opinion regarding the new water distribution plan. We then documented our findings regarding FDA Regulations. Finally, we determined the results from our industrial engineering analysis and cost analysis that enabled us to create a recommended water distribution plan. The final results from our data collection efforts are discussed in this chapter.

4.1 General Population Survey

In order to meet our goal of understanding the public's opinion on the proposed new water distribution system, we analyzed the responses received on 108 questionnaires. With the many biases a convenience sample contains, we used the survey to get an overall assessment of peoples attitudes towards the bags and the new system PRASA hopes to provide.

4.1.1 Survey Results

With recent rises in water prices PRASA is feeling pressure to boost its quality of service. The results of the first question on our survey provided some insight into the current public opinion of the services provided by PRASA. We asked, "I am happy with the current service provided by PRASA."

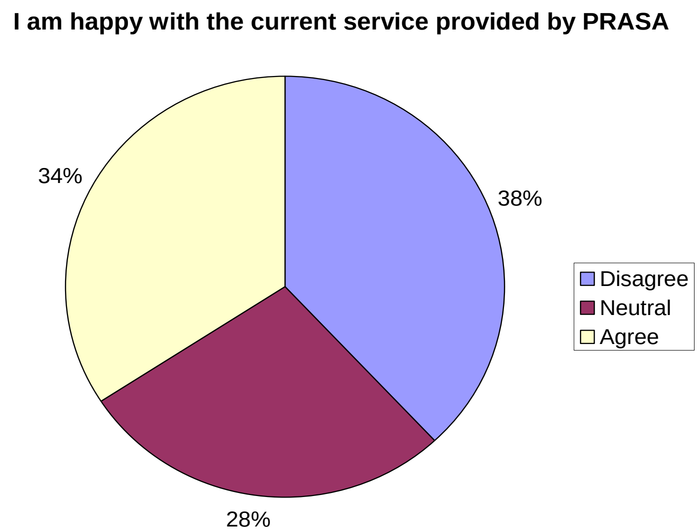

Figure 7 - Public Opinion on PRASA

As can be seen in Figure 7, 34% of the people surveyed were happy with their service, 38% were unhappy with their service, and the remaining 28% were neutral on the subject. The results show that over a third of the PRASA customers interviewed were unhappy with the water service provided to them. Although most people we talked to said they did not like PRASA, over a third were happy with their service.

PRASA wants to improve its quality of service in order to create a more positive image. One way PRASA plans to achieve this goal is by improving upon the emergency water distribution system that is used during any type of service interruption. PRASA's impression is that a large portion of its customer base is unhappy with their service mainly due to these regular water service interruptions. To understand how many customers are regularly affected by service interruptions, we asked, "My Water Service is Regularly Interrupted."

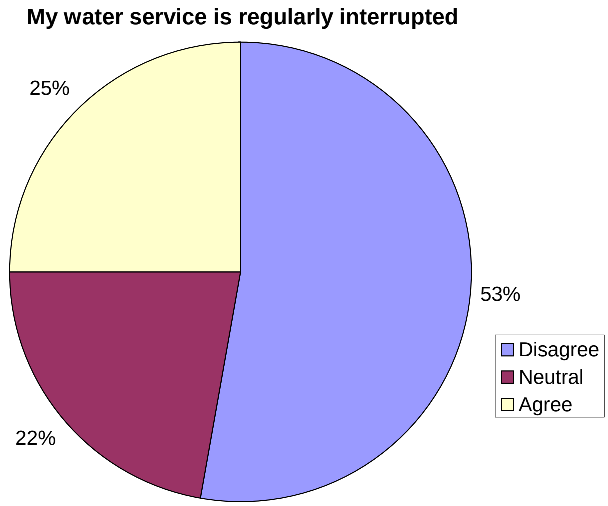

Figure 8 - Service Interruptions

The results show that around 25% of the customers agreed that their water service is disrupted on a regular basis. PRASA believes that the 25% of the customers who lose water service regularly represent a large majority of the 34% of the customers who are unhappy with their water service. Other things that could be causing a poor image of PRASA are the recent rate increase and the previously poor service provided by the privately contracted water companies.

PRASA plans to improve their current emergency water distribution system by supplementing the potable water trucks with packaged water in the form of bags or bottles. Initially, the plan is to begin with the distribution of bagged water. PRASA hopes that the packaged water will enhance the quality of its emergency distribution system. To get an idea of public opinion on the new plan we asked, “I would prefer receiving water in bags over trucks.”

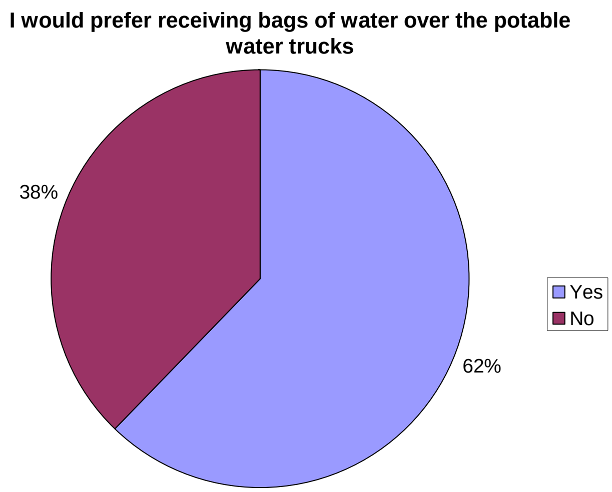

Figure 9 - Water Trucks vs. Bags

Figure 9 shows that 62% percent of the respondents agreed that they would rather receive water in bags than receive water from a potable water truck. This shows that the majority of PRASA's customers who were surveyed believe packaged water to be an enhancement of the emergency services. By speaking to the individuals who preferred the water trucks we found that many of them had health concerns with the bags or thought that the bags would not be enough for them and their family. They would prefer to do it themselves and get as much water as they needed.

Several individuals were concerned about the quality of the bags themselves. One individual mentioned, "Heat from the sun could cause chemicals in the bag to get into the water." This type of health concern was voiced in 6 out the 108 survey responses that were examined. Environmental concerns were voiced in 3 of 108 survey responses. Individuals were worried about the biodegradable aspects of the bags, and the amount of excess waste that would ensue from the bags themselves.

Also, some individuals were worried about cost aspects of the new system. People were worried that the new system would result in the prices of water services rising even more due to the cost of production of the bagged water. This concern was voiced in 2 out of the 108 survey responses.

The majority of the issues concerning the bags of water could be avoided in the future by changing over to bottled water. One of the questions asked in the survey, "Would you prefer bottled or bagged water."

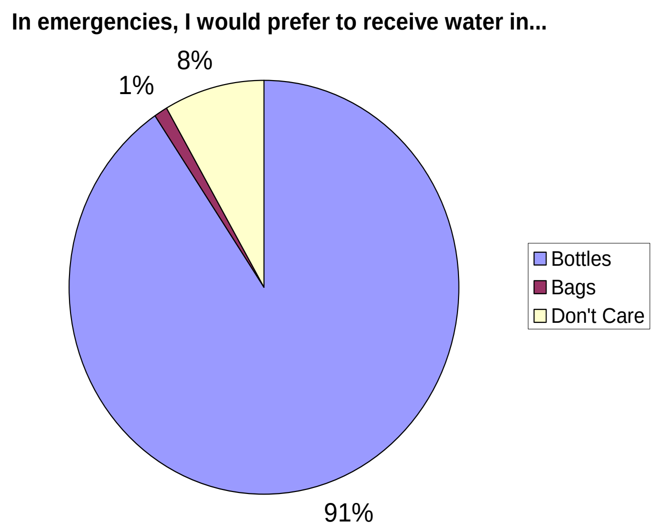

Figure 10 - Bottles vs. Bags

A large majority, 91%, agreed that they preferred bottled water to bagged water. Individuals in Puerto Rico are more accustomed to drinking water from bottles and are much more inclined to trust bottled water over bagged water. Almost all of the health concerns vanished when bottled water was introduced as a possible emergency distribution factor for the future. The only issues that still remained with bottled water were the environmental and cost concerns expressed by the people questioned. Although the cost and amount of waste would increase with bottles, it might be a necessary sacrifice for the public's safety and health.

The major goal of our survey was to determine how the public's attitude about the implementation of the new water distribution system. The final question of our survey was a general question about the bagged water distribution system, “What do you think about these bags of water?”

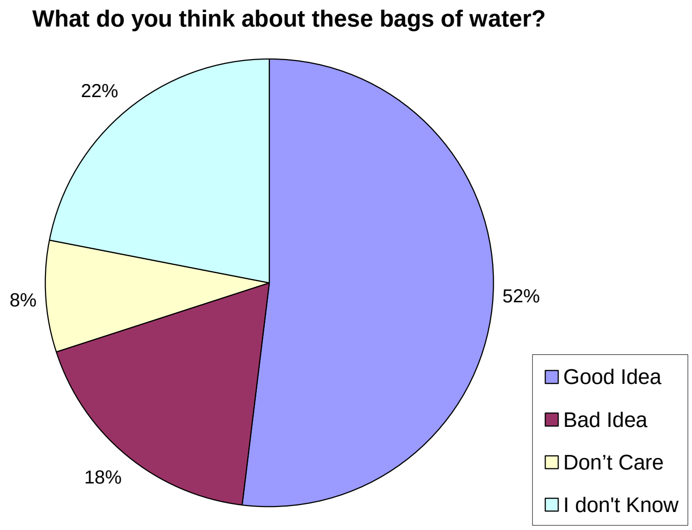

Figure 11 - Thoughts on Bags

The survey showed that 52% of the people surveyed thought the new packaged water system would be a good idea. A smaller quantity, 18%, felt that the new plan was a bad idea. The major issue concerning the new bagged water system is that no one was familiar with drinking water from bags. Almost a quarter of the people, 22%, answered “I don’t know.” These individuals felt that since they had no experience with the bags, they couldn’t make any real decision as to whether or not they would be able to use the bags.

Most of the individuals who were surveyed mentioned that anything that PRASA was doing to make their service better would be a good idea, and these people recognized that the new emergency distribution plan could benefit them in the future. While only a third of the people were dissatisfied with the service PRASA provided, this is still a cause for concern. The goal of any company is to make money and keep the clients satisfied.

With the addition of this service PRASA should have fewer problems when outages occur, leading to a more satisfied client base.

4.2 FDA Regulations and Restrictions

After reviewing Title 21 of the Code of Federal Regulations (CFR), we have gathered all of the regulations applying to the operation of a water packaging facility. We found four main sections of Title 21 that encompass all of what PRASA needs to follow in starting this endeavor. This section of the chapter provides PRASA with the necessary information to ensure that their emergency packaged water system is in full compliance with all regulations.

4.2.1 CFR Part 101 – Labeling

All food products must be labeled under the CFR. The FDA requires manufacturers to label food products in a uniform manner so that customers are familiar with the labeling and can easily recognize the nutrients of the foods they are consuming. An important item learned by reading the CFR concerning labeling was that PRASA might not have to label each package of water individually. By using external packaging on the containers of water PRASA would only have to label the boxes or crates in which they were packaged. Packaging ten bags per box would not only make the transportation of the product easier, but it would also lead to a ninety percent decrease in the labels needed if each package of water were to be labeled. Also an analysis of this section leads to the idea of using a simplified label for the FDA. When a product has an insignificant amount of certain nutritional items such as fat, dietary fiber, and vitamin A, the FDA allows the manufacturer to have a label containing only the most basic information. In addition to the nutrition facts, all labels must contain information about the businesses location, contact information, license number, and the source of the water used in the bottles. After talking to Marieli Ortiz from the Department of Health, we learned that all labels should be in Spanish, the primary language, to be approved in Puerto Rico. Using the information that would be needed on the label, we created a sample label, shown below in Figure 12, to be put on the boxes, bags, or bottles of water. The information that is required on the label is detailed in Appendix C.

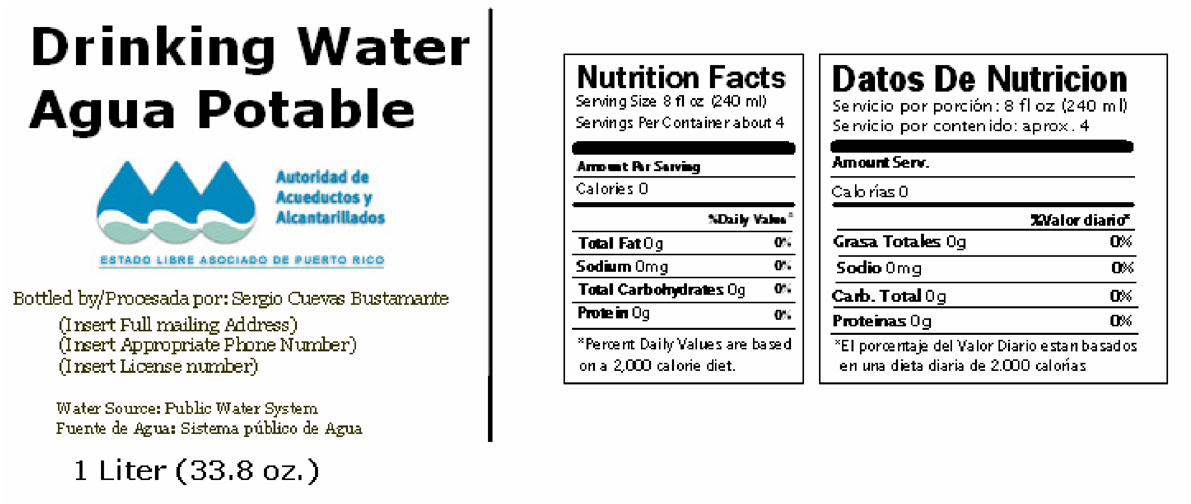

Figure 12 - Potential Label

4.2.2 CFR Part 110 – Good Manufacturing Practices

Part 110 of the Code of Federal Regulations covers the regulations regarding factories and facilities that produce food products. By reviewing these regulations we became familiar with how a facility should be created and then maintained in order to comply with FDA and health department requirements. These regulations showed us exactly what health inspectors are looking for when they conduct unannounced inspections. The section covered the workers, buildings, equipment, and general processes completed in the plant. Everything was covered in depth so supervisors could easily determine if a facility is up to code. All aspects of a plant's operation have to be conducted to assure sanitary conditions and prevent adulteration of the product. A checklist of the regulations in this section can be found in Appendix D.

4.2.3 CFR Part 129 – Processing and Bottling of Water

Bottled water was only recently declared a food product by the FDA so they thought it was necessary to create an entirely new section dealing with the unique new addition of bottled water. While good manufacturing practices cover all facilities involving food, Part 129 deals specifically with bottled water. The good manufacturing practices (Part 110) still apply in addition to everything mentioned in Part 129. While there are some different requirements needed for water facilities, the most important thing we found was that because the water is taken from a municipal water system, the source is approved as long as records of compliance with the EPA are on hand at the facility. The EPA records will take the place of any source testing required by the FDA.

4.2.4 CFR Part 165 – Beverages

Even though Part 165 is labeled as beverages under the CFR, it deals almost entirely with bottled water. Other than a short subpart that defines terms, the rest of the section deals with maintaining product quality. It lists the chemical and biological amounts of contaminants that can be present in the water at anytime. In addition, it goes over how to properly test for the specified contaminants. This is important in assuring the safety of the water according to the FDA and that all required testing is completed.

There are many chemicals to test for and different methods for testing each chemical. Many of the maximum contaminant levels for the FDA regulations are similar to those of the EPA. (See Appendix F for further details.)

One chemical that should be looked into further is chlorine. Chlorine is used to sterilize the water as it leaves the plant. Enough needs to be put in so that it meets the minimum requirements for chlorine set up by the EPA. Because the packaged water will be filled at the facility, a relatively higher level of chlorine will be found in the packages of water. After reviewing the average levels of chlorine in the waters of the Guaynabo filtration plant, we found average levels between 1 and 2.5 mg/L of chlorine. If that number were higher than the maximum FDA amount, additional treatment would have to be applied to the water, such as ozonification or dechlorination. Upon checking the CFR we discovered that the water was well below the 250 mg/L and no additional treatment would be needed.

After reading and summarizing all the regulations that apply to a water packaging system we contacted authorities to verify our findings. We received verification of our findings from Joseph Raulinaitis, a Massachusetts FDA representative, and also a Puerto Rico FDA representative, Jaime Peres. As a last step we met with Marieli Ortiz, a representative from the Puerto Rican Department of Health, who also verified all of our findings and approved our proposed label (previously shown as Figure 12).

4.3 Industrial Engineering

The efficiency of the system is an important objective that was addressed by conducting an industrial engineering analysis. This analysis involved the production facility and the current information concerning water outages.

4.3.1 Machinery

By understanding the production process from beginning to end, the required number of resources may be determined. The first part of the production process will be the operation of the water packaging machines. PRASA can choose to package their water with a bagged system or a bottled system. Many different technologies exist for both systems. As previously mentioned, PRASA already owns four Argenpack 2500® water packaging machines. We decided to focus on providing new information on bottling machines.

In order to obtain a final product, or bottle of water, a number of different methods exist. First is obtaining bottles to fill. This can be contracted to a third party company, where PRASA simply purchases bottles from them. The other option is that PRASA could open an assembly line that creates bottles as outlined in Appendix A. Next, PRASA would need to purchase machines that fill the bottles as described in Chapter 2.4.

4.3.2 Deficient Area Evaluation

To determine the number and the best locations for the water packaging machines, we analyzed daily outage reports and evaluated the reliability of filtration plants across the island. PRASA's Cédula Acción Rápida (CAR) reports document each day's outages. This is used to make sure outages are addressed and proper actions are taken. From July 2002 to July 2004 this information was further compiled into a chart showing the evolution of deficiencies around the island. The data stopped being compiled after 2004 due to the strike PRASA experienced.

The chart below (Figure 13) shows a somewhat steady amount of outages month to month, with the number of customers per day without water generally fluctuating from 10,000 to 20,000. The chart is divided into regions as shown by the color coded legend at the bottom of the chart. While many regions seem to fluctuate month to month, the Metro region has the steadiest outages ranging between 3,000 and 5,000 customers without water per day.

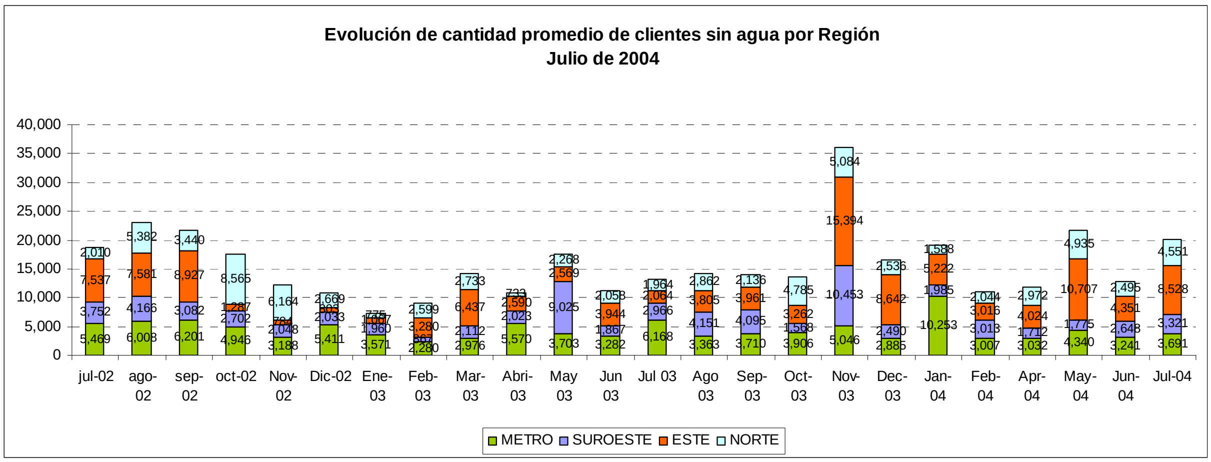

Figure 13 - Average Outages

These data were taken from 2002-2004 when the island was only divided into four regions. With the island now divided up into five regions, more analysis was needed to understand which regions the new outages would fall into. The old regions were Metro, North, East, and Southwest. Recently the South and West were made into new regions by slightly changing the borders of the regions. This has created smaller regions for the North, South, and West but left Metro and East relatively unaffected by the change of regions boundaries.

The average daily outages from each month were taken from each region and displayed so that month-to-month comparisons could be made. By using the charts that produced the graphs, we reorganized the information to show the daily averages per region over the two-year span. This showed us that on average the Metro and East regions have over 25% more outages then the North and Southwest. Also because of the recent change in regions the Metro and East regions will still have more outages in comparison to the North, South, and West.

Region	Daily Average
Metro	4,209
Southwest	3,032.56
East	4,791.28
North	3,093.88
Total	**15,127.56**

Table 1 – Average Daily Water Outages

While the CAR reports are being created daily, we needed to compile them into some useful form. We used random sampling to choose 26 days between October 2005 and March 2006. Each day, two reports are produced, at 0900 hours and at 1700 hours. These reports display the water outages based on the new five-region system. We averaged the results from the 0900 hours report with the data from the 1700 hours report and generated the graph shown in Figure 14.

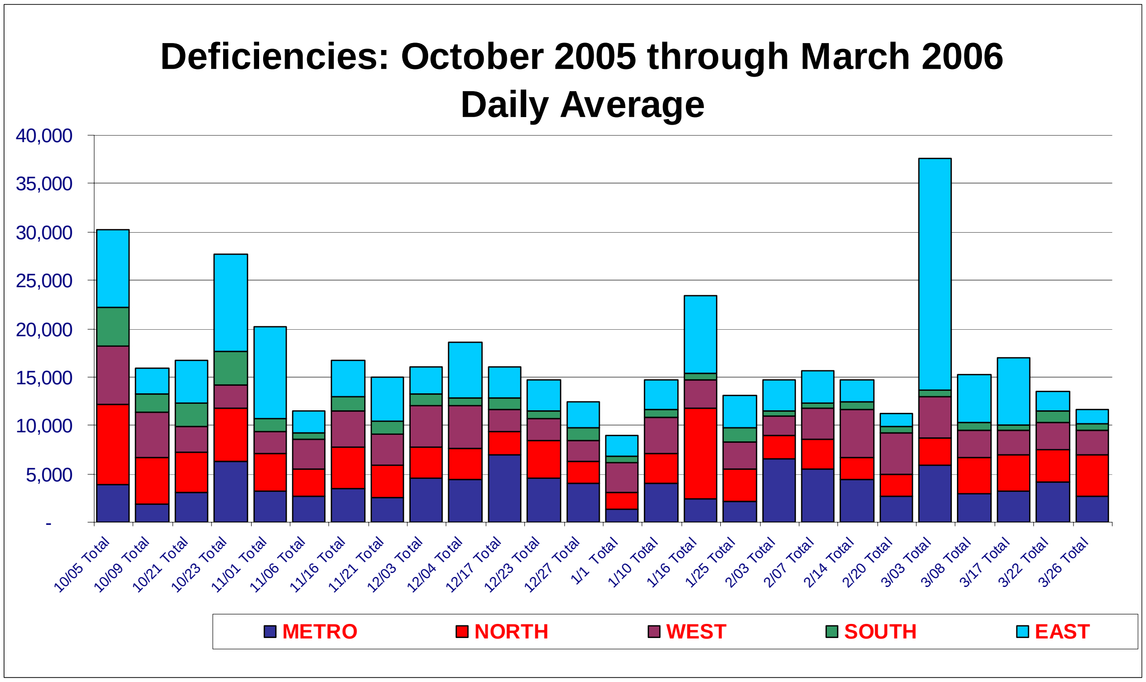

Figure 14 - Averaged Daily Deficiencies by Area

Using these data, we then averaged the days together over the six-month period and were able to determine the average daily outages by area, as shown in Figure 15. In general, the East region has significantly more outages than any other region, while the South region has significantly fewer outages on average than any other region. These data are similar to the reports from 2002 to 2004 in that the East region continues to have the highest number of deficient areas.

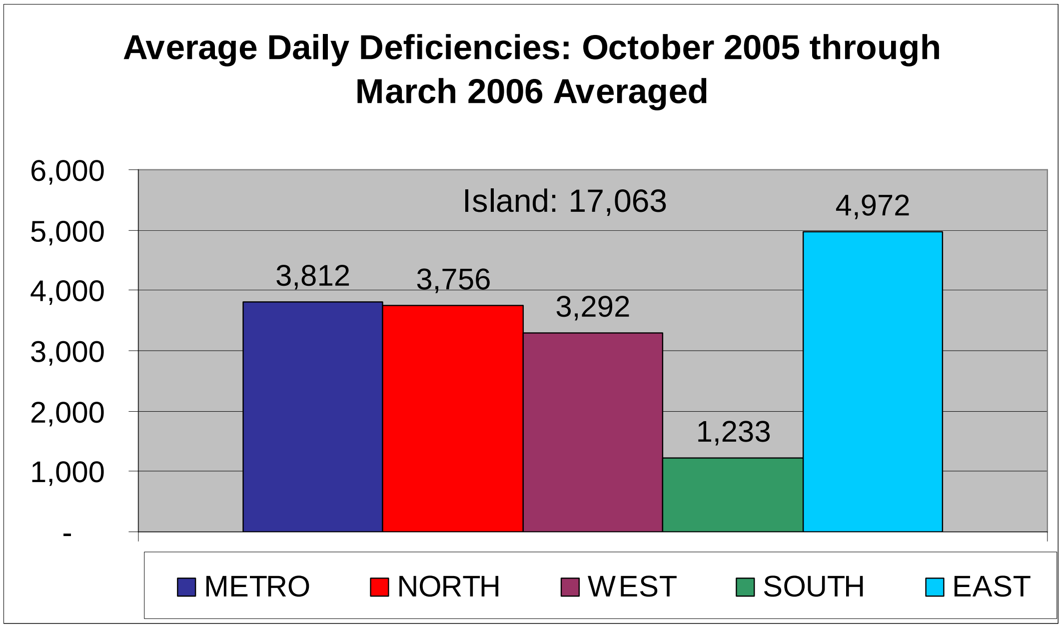

Figure 15 - Average Daily Deficiencies

4.3.3 Reliable Filtration Plants

With the help of two members from the Central Office of Emergencies, Mabel Sanchez and Antonio Pardo, we determined which filtration plants on the island were the most reliable. Placing the packaging machines at reliable filtration plants would ensure packaged water production at times when it is most needed. In our research we found that reliable filtration plants should possess backup power at the filtration plant and also means to get water into the plant with no electricity, we found six. The six filtration plants are:

1. **Sergio Cuevas (Metro) –** Sergio Cuevas, the largest filtration plant on the island, is considered to be the most reliable plant as it is responsible for a large percentage of PRASA's customers. Not only does the filtration plant have a backup generator, but the Carraízo dam that feeds it also has a generator. Located

near a major highway, it is easily accessible. It can produce 100 million gallons of potable water per day (MGD).

2. **Guaynabo (Metro)–** This filtration plant has a backup generator, and is fed by a gravity pipeline from its water source. It can provide 35 MGD.
3. **Ponce Nueva (South)–** This filtration plant also has a backup generator, and is fed by gravity pipes from its water source. It can provide 22 MGD.
4. **Mayaguez/Miradero (West)-** Miradero has two backup generators, and is fed by gravity pipes from its water source. It can provide 22 MGD.
5. **Aguadilla (West)-** Aguadilla has a backup generator and is fed by an open channel water source. It can provide 22 MGD.
6. **Fajardo Nueva (East)–** Fajardo Nueva is a new facility scheduled to open in June 2006. It has a backup generator, and is fed by gravity pipes from its water source to a pump station that is supported by a generator. It can provide 14 MGD.

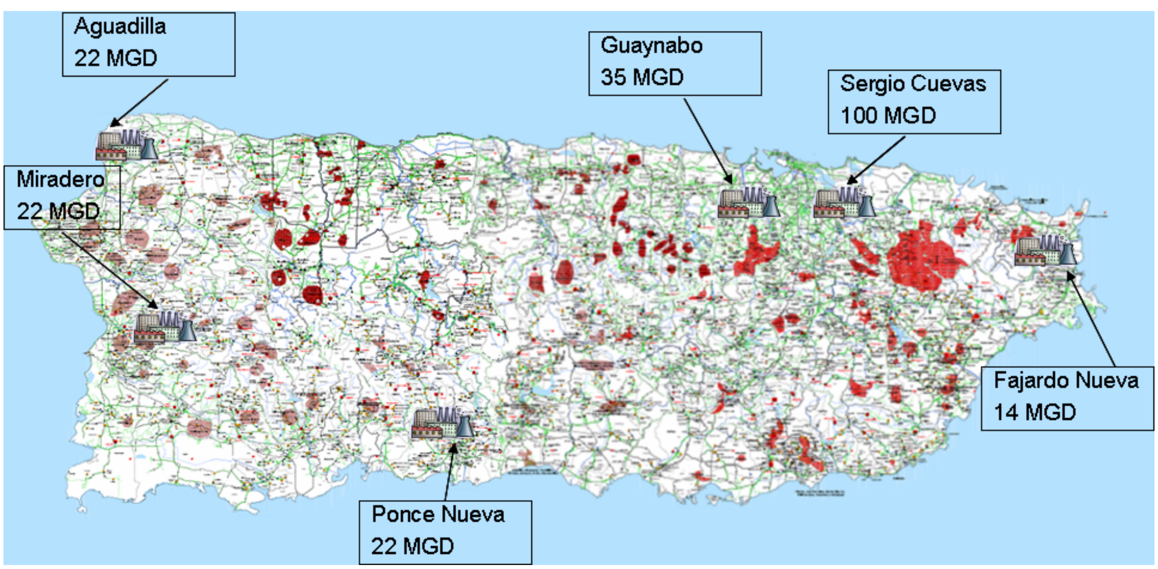

Figure 16 - Locations of Reliable Filtration Plants

4.4 Cost Comparison between Bagged and Bottled Water

PRASA, as discussed previously, owns four machines that make one liter bags of water. With these machines, there is little further capital investment required by PRASA in order to make them function properly. As far as creating bottles is concerned, a significant amount of capital investment would be required, simply because PRASA does not own the machines necessary to make bottles of water. By compiling all the costs required to completely implement a bottled water distribution system, a comparison between the two systems was made.

4.4.1 Bagged Water System

In order for PRASA to begin an emergency distribution system with bagged water, the startup costs would be minimal, since PRASA already owns the four Argenpack 2500® machines. The cost of one bag of water produced by the Argenpack machines is $0.0342. This includes electricity, staffing, maintenance, and all raw materials. This roughly $0.03 per one-liter bag translates to $710,712.82 while operating at 8 hours a day for 260 days a year and producing 20,800,000 bags per year.

As for the external packaging, the Flexible Packaging Group quoted a price of $0.41 per cardboard box when ordering 10,000 units. Since significantly more than 10,000 units would be required per year, there is no concern about this order size being too large. The boxes quoted are designed to support ten bags per box. Since 20,800,000 bags could be produced in a year, 2,080,000 boxes would be needed each year. This would amount to a cost of $852,200.00 per year for bags. These boxes would also need to be replenished and cannot be reused because they would be distributed.

An alternative to using boxes are crates that can be purchased once and reused. The Freund Container Company offers 330 gallon crates for $473.20 each. This is, however, an initial investment and would not need to be reapplied every year. This would bring the first year total cost for the bagged system to $773,154.42 or $0.0372 per bag of water. Further details of the individual costs and analyses are available in Appendix H including a comparison of varying production output.

4.4.2 One Liter Bottled Water System

In order for PRASA to begin an emergency distribution system with one liter bottles of water, a number of startup costs are present, that are not required with a bagged water system. These startup costs would primarily be absorbed by the first year of implementation for this system. This is the major difference between implementing a bottled water distribution system versus a bagged water distribution system. Figure 17 shows the comparison for the first year and subsequent years, with respect to total cost of implementing a 1-Liter bottled water distribution system. In order to see an itemization of these costs, see Appendix I.

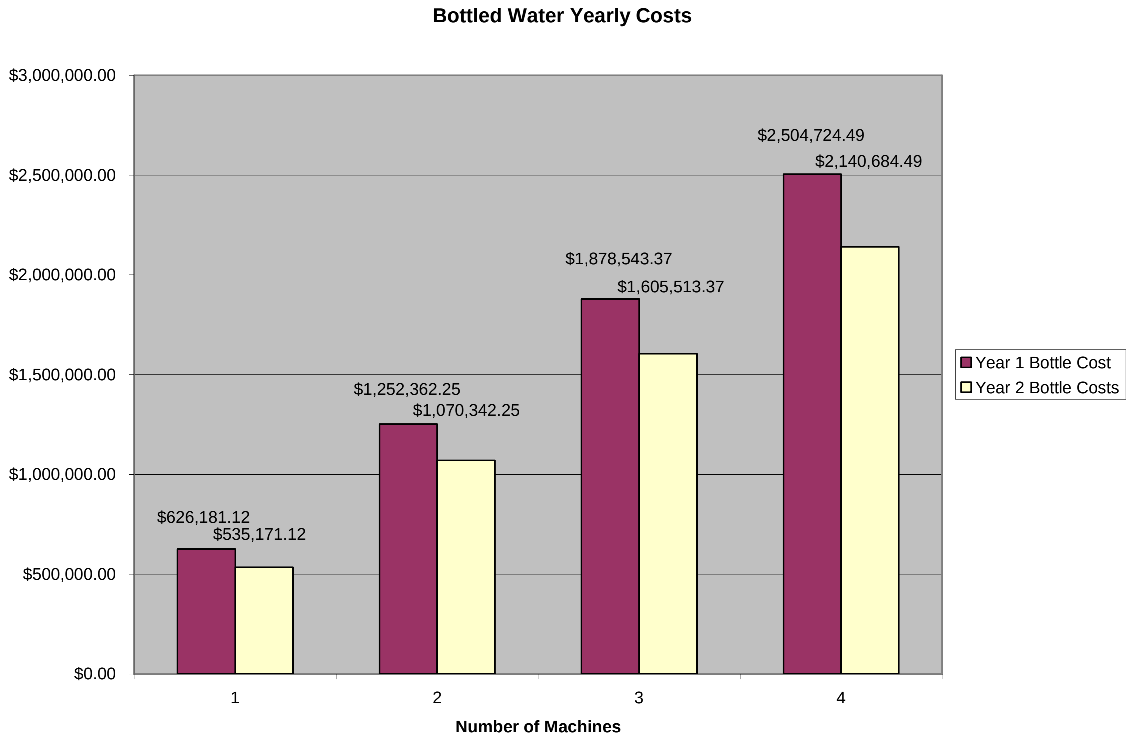

Figure 17 - Yearly Costs for One Liter Bottled Water System

The yearly cost of one liter bottles translates to $0.12042 per bottle in the first year and $0.10292 for subsequent years as shown in Figure 18.

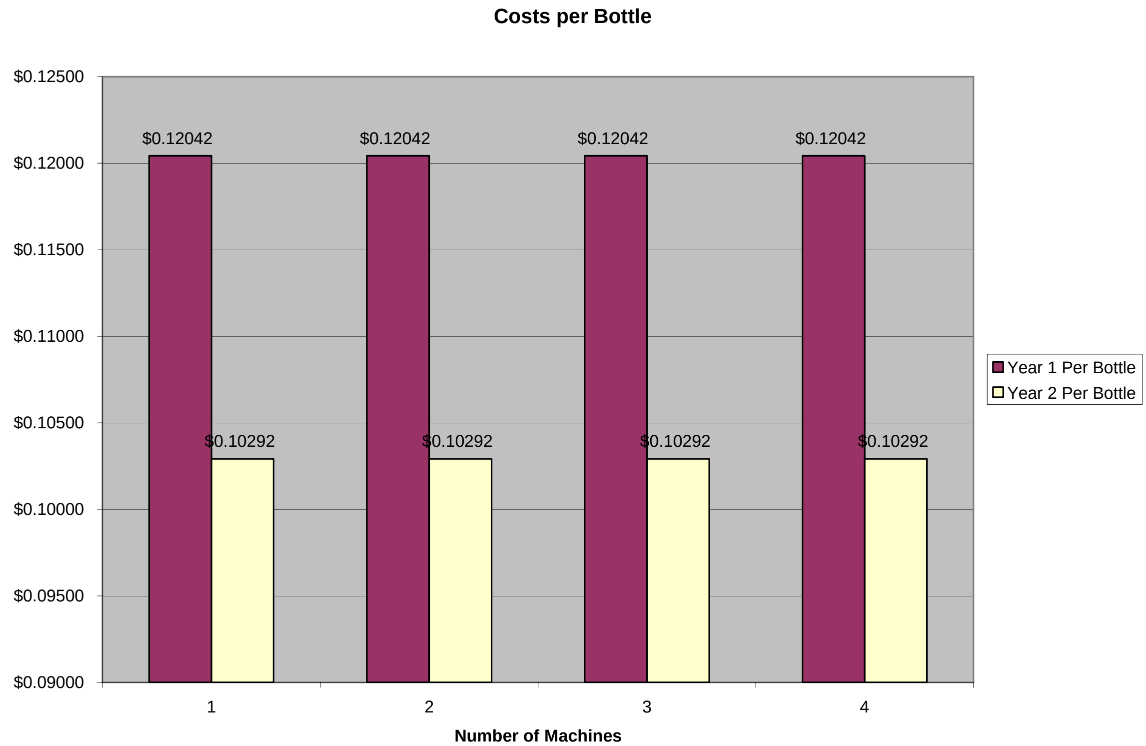

Figure 18 - Cost per One Liter Bottle by Year

4.4.3 One Gallon Bottled Water System

Similar to one liter bottled water, startup costs will be present with one gallon bottled water systems that are not required of a bagged water system. Figure 19 shows the comparison for the first year and subsequent years with respect to total cost of implementing a bottled water distribution system. To see an itemization of these costs, see Appendix I. Also located in Appendix I, are the detailed calculations used to determine the numbers discussed in this section.

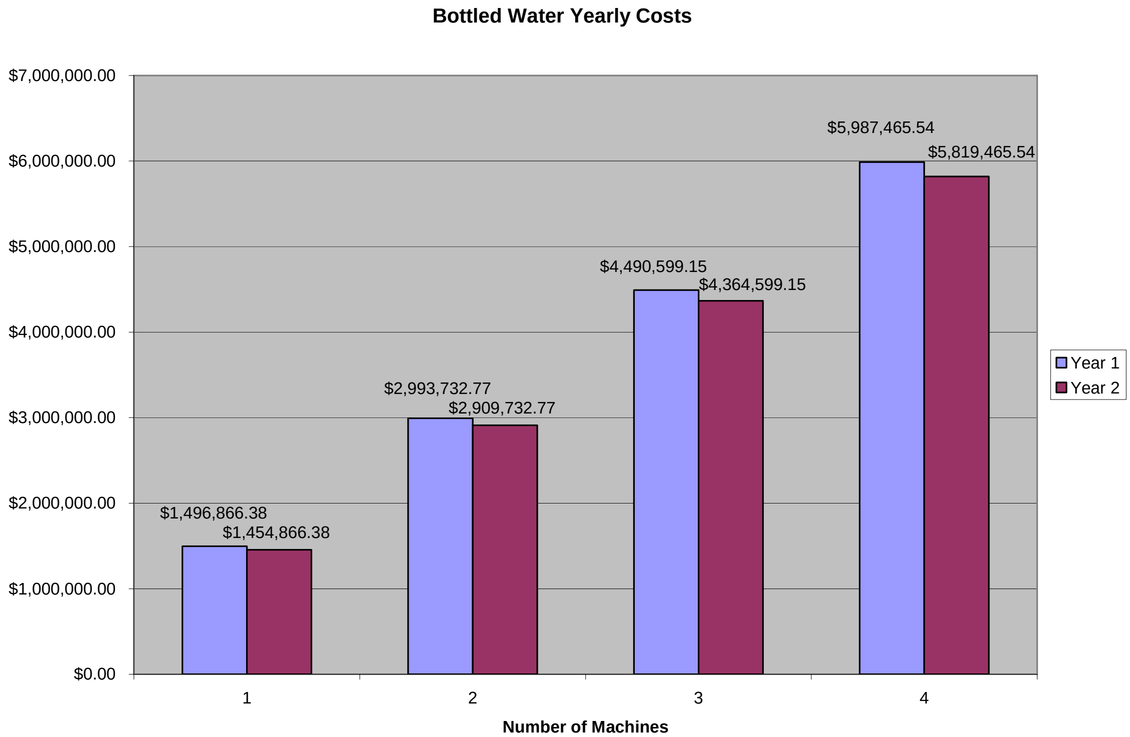

Figure 19 - Yearly Costs for One Gallon Bottled Water System

As seen in Figure 19, the first year cost of a bottled water system with four machines, capable of producing 20,800,000 bottles of water, would cost almost $6 million. This yearly cost, however translates to a cost of $0.28786 per bottle. In subsequent years, the yearly cost of nearly $5.82 million translates to a per bottle cost of $0.27978, as shown in Figure 20.

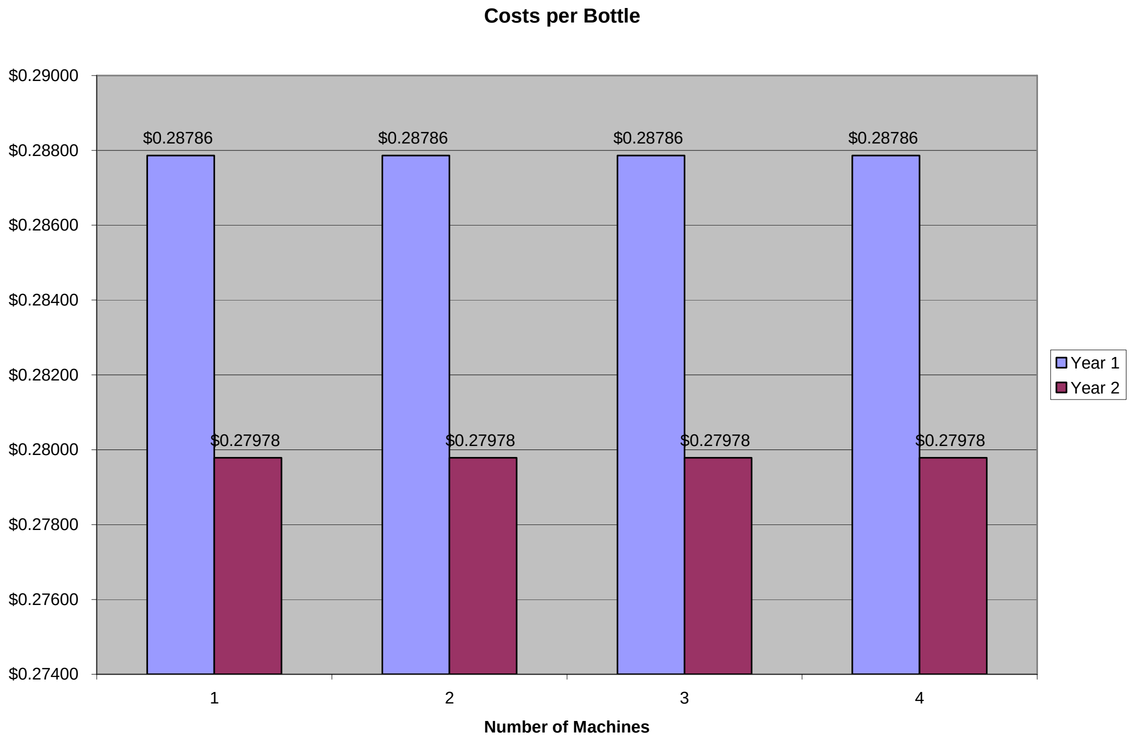

Figure 20 - Cost per One Gallon Bottle by Year

4.4.4 Bags versus Bottles

In order to analyze the cost difference between bags and bottles we created a comparison table seen in Table 2.

Packaging	Year 1 Operating Cost	Year 1 Per Package Cost	Year 2 Operating Cost	Year 2 Per Package Cost
Bags (1 L)	$773,154.42	$0.0372	$710,712.82	$0.0342
Bottles (1 L)	$2,504,724.49	$0.12042	$2,140,684.49	$0.10292
Bottles (1 Gal)	$5,987,465.54	$0.28786	$5,819,465.54	$0.27978

Table 2 – Comparison of Bags and Bottles (4 Machines Each)

Table 2, above, shows the comparison of bags and bottles for the yearly costs as well as the per package costs. Four bags combined are approximately equivalent in volume to one gallon bottle. Four bags cost $0.1488, which is approximately 52% of the cost to produce a one-gallon bottle for the first year and approximately 49% for the same production in the second year.

Figure 21 shows the total costs for creating packaged water by year with varying numbers of machines. With each additional machine in a new location, for either bottles or bags, more overhead is generated and higher total cost, however the cost per package does not change drastically.

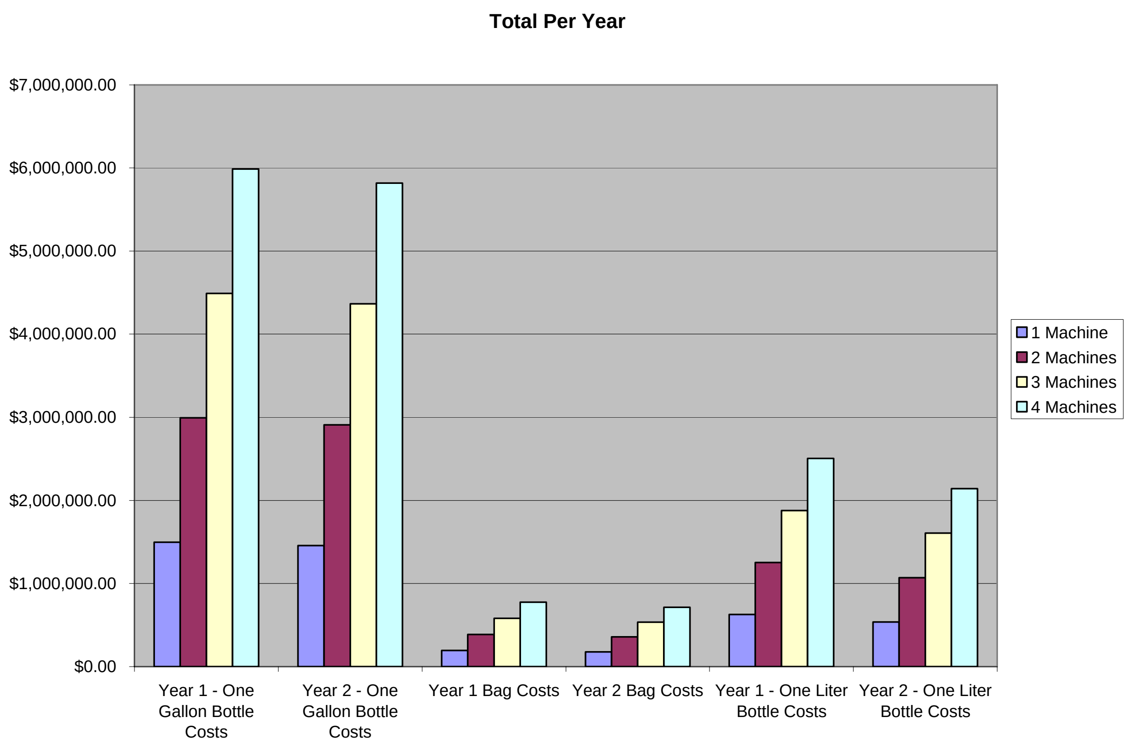

Figure 21 - Total Production Costs for differing Configurations

Another element to compare, however, is the price of water that is placed into the potable water trucks or packages versus the price of the completed package. For this comparison we ignored the cost of transportation via the potable water trucks or other styled trucks that can carry packages of water. $0.001827157 per gallon is the approximate rate at which PRASA sells their water to consumers. This is the product that is being put into the contracted water trucks. In comparing the production costs of packaged water to unpackaged water, a one gallon bottle of water costs 15,754% more than one gallon of unpackaged water. Similarly, a one liter bottle costs 24,947% more than one liter of unpackaged water. Even a one liter bag of water produced through our proposed system costs 7,078% more than producing one liter of unpackaged water. Figure 22 displays the percentage increase for the respective packaging types.

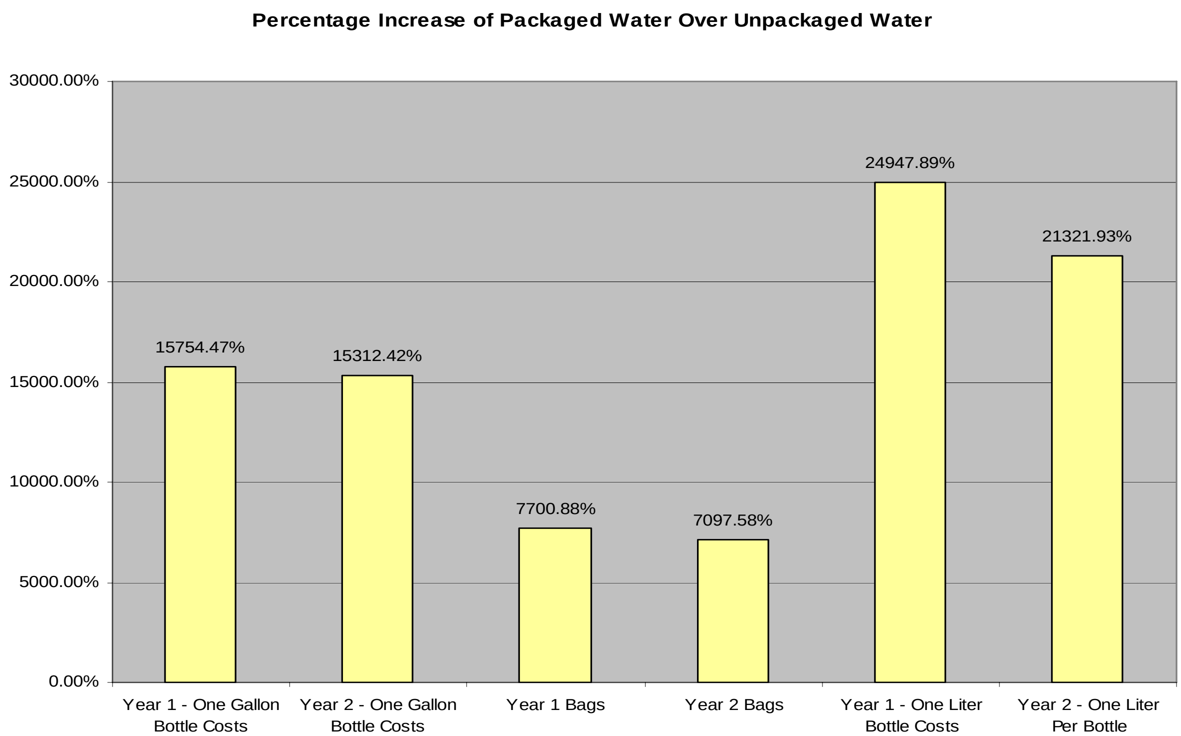

Figure 22 - Percentage Increase of Packaged Water Over Unpackaged Water

The data we obtained were essential to make recommendations concerning the new distribution system PRASA hopes to begin. The wide range of data we collected can be applied to each recommendation individually in order to meet our objectives and solve the problems we hoped to address during the start of this project.

5. Conclusions and Recommendations

As presented in this report, there are many different options that PRASA can choose for an emergency packaged water distribution system. After analyzing our results and analyses, we have created several recommendations that will detail the possible implementation of an emergency distribution system for packaged water.

5.1 Packaging System

The following recommendations were made with PRASA's best interest in mind. These recommendations focus on all of the needs of a suitable emergency water packaging system.

5.1.1 FDA Recommendations

Through research we discovered that the Puerto Rican Department of Health follows the guidelines and standards of the FDA in the packaging of water. Every section within the Code of Federal Regulations (CFR) has to be followed as it applies to a specific facility or production process concerning bottled water. By carefully reviewing the CFR, we determined which codes directly apply to the packaging of water. It is extremely important to follow these regulations because it not only ensures that the public will receive an end product that is safe to drink, but it will also keep PRASA's packaged water production within regulatory guidelines. Complying with all the regulations will allow PRASA to pass random health inspections by the Department of Health in Puerto Rico. We recommend that PRASA follow the checklists, located in the appendices that were created from the information from the Code of Federal Regulations.

In addition, we recommend that PRASA's Compliance Department take on the responsibility of ensuring that the production of water is compliant with the FDA. The compliance department makes sure water facilities pass Department of Health inspections and will continue to make sure PRASA passes such inspections in regard to the packaging of water.

5.1.2 Filtration Recommendations

The current water filtration plants around the island are required to follow the EPA regulations for contaminant levels. The levels of contaminants found in the water produced by filtration plants meet both the FDA and EPA standards for bottled water. Therefore, to avoid any public scrutiny involving further treatment to any packaged water products, it is recommended that the water undergo no further filtration. People need to know that the water running through the pipes is the same as the water in the bags and that it is safe to drink.

5.1.3 Packaging Facility Recommendations

An extremely important aspect for finding suitable facilities was the ability for them to operate when there is a power outage. Of the six that would be able to operate without power, we chose five facilities to support the island with the emergency packaged water. The five filtration plants we chose were Sergio Cuevas (Trujillo Alto), Fajardo Nueva, Guaynabo, Ponce Nueva, and Miradero (Mayaguez). The five locations were chosen to support the five regions. Aguadilla or Guaynabo could have been chosen to help support the Northern region. Guaynabo was chosen over Aguadilla because Aguadilla is fed by an open channel. In the past, the channel has experienced problems due to the limestone walls collapsing during hurricanes. With this potential risk Guaynabo seems to be the more reliable plant to support the Northern region. The support of the island would follows as such:

1. Sergio Cuevas – This facility would mainly support the areas of Carolina, Canovanas, and most of the Metro region.
2. Fajardo Nueva – This facility would support the majority of the Eastern region and also support Vieques and Culebra. Water could be shipped to the islands on the cargo ferry when they are in need.
3. Guaynabo – This facility would help support the Metro region, if needed, and would be in charge of providing the Northern region with emergency water.
4. Ponce Nueva – This facility would support the Southern region. In addition it can supply water to the lower Northern region. Because the Southern region has the least amount of outages, it can be used to support the West and East during local outages.
5. Miradero – This facility would support the Western region. It is centrally located within the region and easily covers the region. It can assist Guaynabo with the Northern region by providing water to the Western area of the North region.

After visiting and evaluating two of the most reliable filtration plants on the island, the Guaynabo filtration plant and the Sergio Cuevas filtration plant, we believe that the best initial location for the packaging machines would be at the Sergio Cuevas plant. With a centralized location close to a major highway, Route 3, distribution of the packaged water by trucks would be more convenient than the rural and narrow roads and the mountainous terrain that must be traveled through to reach the Guaynabo facility.

Future packaged water machinery should be placed in locations according to the outage information determined in the deficiency results. This will ensure that the areas most prone to deficiency problems are the first to receive water supplies. Additional machines should be placed in the North and West regions, which each face similar outages to the Metro Region. The Southern region should be the last priority, as it averages less than one fourth of the number of outages of any other region.

5.1.4 Storage Recommendations

The option of storing the packaged water is dependent on the usage of the system. If PRASA chooses to use the packaged water distribution system on a daily basis to serve all water outages, then storage is not recommended. The packaged water would be produced and distributed to people right away. However, if PRASA chooses to use the system less frequently, during large emergencies such as a hurricane or large service outages, storage is recommended.

Storing packaged water would enhance the level of preparedness of the emergency water distribution system. Storage facilities would be the most beneficial to regions that would be hardest to reach in emergency situations. For example, the islands of Vieques and Culebra could be supplied with potable water easily if storage facilities were located on each island. Other hard to reach areas that would benefit from having storage facilities include all communities that are high in the mountainous regions of the island, where it is difficult for large vehicles to access.

If the packaged water is stored, it is important that these storage facilities, like the packaging facilities, be in compliance with all FDA regulations. (Appendix D and Appendix E would also apply to the storage facilities.)

5.1.5 External Packaging Recommendations

Products are usually packaged further in an attempt to make them easier to ship and easier for the consumer to handle. We looked at cardboard boxes and plastic crates. To transport packaged water from the packaging facility to the customer, we recommend using plastic crates. Crates can be reused every time and while the initial cost may seem high, after extended use, the overall cost is far less than using cardboard boxes. Another advantage of the crates is that they will not be ruined or damaged in the case that a bag or bottle breaks and leaks during transportation.

5.2 Use of a water packaging system

There are two different ways that water packaging machines could be used by PRASA. They could either be used on a daily basis for basic infrastructure problems or they could be saved for drastic occurrences such as hurricanes or major infrastructure problems.

Due to the high costs of production, using either packaged water system on a regular basis would require additional expenditures. However, because the bagged water machines have already been purchased, are more efficient in production, and less costly to maintain, we recommend that they be used instead of bottled water. Using the bags on a small scale will give PRASA an idea of everything that would need to be accomplished from a potable water system. Bottled water is only recommended if PRASA is considering purchasing more machines to better cover the island. We recommend any new machinery purchased to be bottling machines because of the social aspects discussed earlier in the report. The clients of PRASA would be much happier with a bottled system then a bagged system.

Currently the Argenpack 2500® machines are located at the Guaynabo filtration plant and are not functioning properly. When we visited the facility we received ten sample bags produced by a machine. The bags were not filled to capacity and yet eight of the ten bags broke within five weeks. We recommend that the machines be fully calibrated to ensure product quality. A range of available thicknesses for the bag material can be found within the product information of the Argenpack 2500®. Different plastics and thicknesses could help improve the seal of the bag. We recommended that further research is done to understand what thickness of the bags is most effective for the Argenpack machines.

5.3 Educating Communities

In our sampling of the population, we found that almost no one was familiar with bagged water. If a bagged water system were to be implemented without informing the public, it could cause dissatisfaction. Before any change to the current system is made the public should be made aware of bagged water so they know what to expect. We recommend that the bagged water product be marketed to the public before implementation to build awareness and ensure that residents take full advantage of the system in the event of an emergency. This can be accomplished through advertisements placed in monthly water bills, newspapers, and television. Also, the bags of water can be handed out at social events throughout the island so that the public can experience the product first-hand. This awareness can be carried out by the public relations department at PRASA.

5.4 Final Thoughts

Much more work still needs to be accomplished in order to develop a packaged water system for the island. How much of the current system will be supplemented by the packaged water system still needs to be determined. Until that is determined it will be impossible to know exactly how much machinery or packaged water is required.

Another option that will need to be evaluated further is the possible grant FEMA may provide for emergencies. In the past, FEMA has spent an inordinate amount of money trying to supply the island with water during a hurricane. If FEMA could use PRASA’s bottled water for both Puerto Rico and the Virgin Islands, it is possible that FEMA would subsidize some of the initial costs to establish PRASA’s bottling facilities.

PRASA still has much work to do on their infrastructure. By continuing with the Capital Improvement Plan, the infrastructure will hopefully improve and the potable water trucks and a packaged water system would not be needed as much as they are now. Until then, we know that with the addition of a packaged water system, PRASA will be better prepared for emergency situations and be able to supply water at all or most of its customers during an emergency.

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APPENDIX A: PET Blow Molding Process

To bottle water, both potable water and bottles are needed. Since water is, in general, available to PRASA, this section will focus on the creation of bottles. While companies exist, which produce bottles, it is also possible for a company, such as PRASA, to manufacture the bottles themselves. The most common beverage bottles used by companies such as Coca-Cola® and Pepsi® are Polyethylene Terephthalate (PET) bottles which are produced with a PET Stretch Blow Molding Machine (Michael Putnam, personal communication, March 23, 2006)

Figure 23 - Various PET Preforms for Creating Bottles (PET Preform, 2006)

A stretch blow molding machine starts with what is called a preform. This preform can either be manufactured through an injection molding process, or can be purchased from most blow mold machine distributors. The preforms themselves look like large test tubes with one end open for filling with air. Figure 23 shows a number of different preforms of different weights and applications. The larger weight preforms are for larger bottles, such as those used for water dispensers.

The preforms are placed in the reservoir of the machine. This reservoir may be just a bucket or might be a slot load chamber, similar to the clip on a hand gun, depending on the machine. The preforms are loaded individually onto a conveyer belt that locks them into a uniform position so that the air can be blown into them. (Simon Cai, personal communication, March 24, 2006)

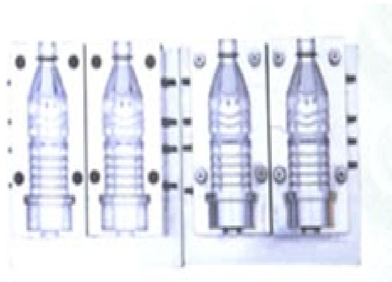


Figure 24 - 500ml Bottle Mold (Simon Cai, personal communication, March 24, 2006)

The preforms are first heated, and then enclosed by a mold that is the shape of the desired bottle. Once in the mold, high pressured air is forced into the mouth of the preform and it expands to the shape of the mold. Figure 24 shows both sides of a mold for two 500ml bottles. Once the bottle is out of the mold, it will need to cool and then is dropped to a reservoir outside the machine. Now the bottles are ready to be filled.

APPENDIX B: Survey Questions

Autoridad de Acueductos y Alcantarillados

In Conjunction With

Worcester Polytechnic Instiute

Emergency Water Distribution Survey

1. Age: 18-25 26-35 36-55 55+

2. Gender:

3. Occupation:

4. Town:

5. I am happy with the current service provided by the AAA.

Strongly Disagree Disagree Neutral Agree Strongly Agree

6. My water service is regularly interrupted.

Strongly Disagree Disagree Neutral Agree Strongly Agree

7. I always keep extra water on hand in case of a service interruption.

Yes No

9. Have you ever received water from the potable water trucks?

Yes No

If yes, would you prefer receiving 1Liter bags of water as opposed to getting water from the trucks?

Yes No

10. In case of emergency, would you prefer to receive water in …

Bags or Bottles

11. What do you think about these bags of water?

Thank you for taking the time to participate in our study!

APPENDIX C: FDA Regulation Evaluation (CFR Part 101 – Labeling)

- Each package needs a principal display panel clearly labeled.
- Directly to the right of the principal display panel an information panel is needed.
- Lettering must be legible and larger then 1/16 of an inch in height.
- A petition to not follow all labeling codes can be petitioned using 21 CFR part 10.
- The principal label must identify the commodity in terms of:
  - Name of the product.
  - The common name of the product.
- The ingredient list should be directly below the nutrition label and preceded by the word ingredients.
- An ingredient list is not needed as long as nothing is added and the ingredients are displayed on the primary panel.
- The name used by the business and place of business of the manufacturer, packer, or distributor must be conspicuously labeled.
- The place of business must include:
  - Street address, city, state, and zip code.
  - The street address can be omitted if it is shown in the current city or phone directory.
- Nutritional information must be provided.
- The serving size for water is 240 ml but can be approximated to 250 ml per serving to get four servings for one liter.
- Beverages must be expressed in fluid ounces or milliliters.
- When rounding servings per container "about" is used to indicate rounding.
- Servings shall be rounded to the nearest whole number unless there are between two and five servings then it can be rounded to the nearest half a serving.
- The following components must be included in the nutrition label:
  - Total Calories: less than 5 can be labeled as zero.
  - Total Fat: less than .5 grams can be labeled as zero.
  - Total Carbohydrate: less than .5 grams can be labeled as zero.
  - Protein: less than .5 grams can be labeled as zero.
  - Sodium: less than 5 milligrams can be labeled as zero
  - Any vitamins and minerals that have been added to the food.
- Fonts and line format for nutrition label can be found in Appendix B of this section in the CFR.

APPENDIX D: FDA Regulation Evaluation (CFR Part 110 – Good Manufacturing Practices)

Subpart A – General Provisions

- The plant management must control sick workers and not allow anyone with an abnormal source of bacteria into the facility.
  - Workers must report sicknesses and open wounds to the management
- Workers must conform to hygienic practices while on duty to protect against contamination, which includes:
  - Wearing outer garments suitable to the operations.
  - Maintaining adequate personal cleanliness.
  - Washing hands thoroughly and whenever starting work, returning to work, or if hands become dirty in some way.
  - Remove unsecured jewelry or other objects which may fall into machinery or containers.
  - Wearing hair nets where appropriate.
  - Maintaining gloves if used.
  - Storing clothes or personal items in a separate area.
  - Taking any other necessary precautions to protect against contamination of food.
- Personnel responsible for identifying contaminations should have proper background or experience.
- Responsibility with conforming to the code must be clearly assigned to supervisors.

Subpart B – Buildings and Facilities

- The grounds around the facility must be kept in a condition that will protect against contamination, to include.
  - Properly storing equipment, removing waste, and proper upkeep of lawn or shrubs.
  - Maintaining roads, yards and parking lots as to not constitute a source of contamination.
  - Adequately draining areas that may contribute to contamination.
  - Operating systems for waste treatment and disposal in an adequate manner.
- Plant buildings must be constructed to ensure sanitary conditions to include:
  - Provide sufficient space for equipment and storage of materials.
  - Be constructed so that floors walls and ceilings may be cleaned and kept in good repair.
  - Drips or condensation cannot contaminate the product or equipment.
  - Adequate lighting must be provided throughout the facilities.
  - Adequate ventilation must be provided throughout the facilities

- Buildings and fixtures must be kept in good repair to prevent to prevent water from becoming adulterated.
- Cleaning substances in the facility must be safe for use in the factory and this can be proved with a suppliers guarantee, certification, or examination for contaminates.
- The only toxic materials that may be stored in the plant are:
  - Those used to maintain clean conditions
  - Those used in laboratory testing.
  - Those necessary for equipment maintenance.
  - Those necessary for plant operations
- Toxic cleaning compounds must be identified and stored in a manner to protect bottling process.
- No pests shall be allowed in any area of the plant with the exception of guard dogs and guide dogs in areas where contamination to the product is unlikely.
- Food-contact surfaces must be cleaned as often as necessary to protect against contamination.
- Water shall be supplied to all areas of the plant where it is necessary.
- Plumbing must be of adequate size and proper design in order to:
  - Carry sufficient quantities of water to required locations
  - Properly convey sewage from the plant.
  - Avoid causing a contamination to water supplies or equipment.
  - Provide adequate floor drainage.
  - Not cause backups or cross contamination between sewage pipes and water carrying pipes.
- Sewage must be disposed of properly.
- Every plant must have adequate readily accessible toilet facilities including:
  - Keeping them clean and in good repair.
  - Providing self closing doors.
  - Providing doors which do not open directly into processing areas unless steps are taken against contamination such as double doors.
- Hand washing facilities must be adequate and convenient and include:
  - Water at a suitable temperature.
  - Sanitary drying methods or devices.
  - Signs directing employees involved in the packaging of the product to wash hands before work, and after each absence from work.
  - Devices, such as water control valves, designed to protect against recontamination of clean hands.
  - Trash containers designed to protect against contamination.
- Garbage must be collected, stored, and disposed of in a manner to prevent contamination or a breeding ground for pests.

Subpart C – Equipment

- All plant equipment must be designed of such workmanship and material to be adequately cleanable and properly maintained.
  - These designs must also preclude the adulteration to the product.
- Seams on food-contact surfaces must be smoothly bonded to prevent accumulation of unwanted particles.
- Holding, conveying and manufacturing systems, including pneumatic, closed and automated systems, must be of a design that enables them to be maintained in a sanitary condition.
- Instruments and controls used for measuring undesirables in the product must be accurate and adequately maintained for their use.
- Compressed air or other gases mechanically introduced into food or used to clean food-contact surfaces must be designed and used so that the product is not contaminated.

Subpart E – Production and Process Controls

- All operations must be conducted in accordance with adequate sanitation principals.
- Overall sanitation of the plant must be under supervision of one or more competent individuals assigned to the task.
- All reasonable precautions must be taken to ensure that processing of the product will not lead to contamination.
- Storage and transportation must be carried out under conditions which will protect the product from contamination as well as protect the package from deterioration.

Subpart G – Defect Action Levels

- Levels of defects can be present in food and the FDA regulates those numbers for bottled water clearly in part 165.110.
- However, it will not comply with FDA regulations if the food as been adulterated as defined in section 402 of Federal Food, Drug and Cosmetic Act and still meets standards of 165.110.
  - The failure to limit adulteration takes precedence.

APPENDIX E: FDA Regulation Evaluation (CFR Part 129 – Processing and Bottling of Water)

Subpart B – Buildings and Facilities

- Bottling room must be separate from other plant operations, by tight walls ceilings and self closing doors.
- If they aren't packaged in a sealed system, adequate protection has to be taken to preclude contamination.
- If packages need to be washed and sanitized it has to be done in the packaging room.
- Adequate ventilation has to be present to minimize condensation.
- No processing rooms can open directly into rooms used for domestic household purposes.
- Is there air under pressure directed at product or product water-contact surface.
  - If so it must be free of oil, dust, rust, excessive moisture and extraneous materials.
  - Must not affect the bacteriological quality of the water.
- Lockers and lunchrooms must be separate from plant operations and storage areas.
- Lockers and lunchrooms must have self closing doors.
- No packaging or wrapping materials can be stored in locker or lunchrooms.
- The product water supply for each plant shall come from an approved water source.
- Samples must be taken and analyzed as necessary to assure safety, to include:
  - At least weekly for microbiological contaminants.
  - At least yearly for chemical contaminants.
  - At least once every four years for radiological contaminants.
  - All testing must be recognized and approved by the agencies with jurisdiction over the water source and kept on record.
- Firms that use a public water system for source water may substitute public water system testing results or certificates which show full compliance with EPA standards.
  - These can be found at Title 40 CFR parts 141 and 143.

Subpart C – Equipment

- All equipment must be suitable for its intended use
- All product water-contact-surfaces must be constructed out of nontoxic/nonabsorbent material. (see section 409)
- Storage tanks must be able to be closed to exclude foreign matter

- After cleaning, all equipment must be stored to assure drainage and be protected from contamination
- Prior to use, packages shall be examined and washed/sanitized as necessary.
    - Unfit packaging material can be reprocessed or discarded.
- Product water-contact surfaces must be clean and sanitized.
    - Free of scale, evidence of oxidation, and other residue.
    - Inspected as often as necessary and any problems remedied immediately.

Subpart E – Production and Process Controls

- All multi-service shipping cases shall be maintained so they don't contaminate the primary water containers or the product water itself.
- Cleaning solutions must be sampled as often as is necessary to ensure adequate cleaning and sanitizing.
- Sanitizing operations must meet one of the ones following at a minimum for adequate sanitation:
    - Steam or hot water in an enclosed system at 170 ˚F for at least 15 minutes or 200 ˚F for at least 5 minutes.
    - Chemical sanitizers must be equivalent in bacterial action to a two minute exposure of 50 parts per million of chlorine at 57 ˚F.
    - .1 part per million ozone water solution in an enclosed system for 5 minutes.
- When containers are sanitized using a substance other then one provided in 178.1010 the substance must be rinsed off before containers are used.
    - Part 178.1010 lists over 40 compounds and the ratios of cleaning substances.
- Each unit from a batch of continuous production line must be identified by a production code.
- The packaged water must be inspected both visually or electronically to assure proper sealing, coding, and labeling.
- At least once each three months a bacterial swab should be taken from at least four containers. No more then one of the four may exceed one bacterium per milliliter of capacity.
    - The tests must be in conformance with whatever agencies have jurisdiction.
- The plant must analyze product samples as follows:
    - For bacteriological purposes, analyze at least once a week a batch from a representative sample from a continuous production run. The representative sample should consist of the primary containers.
    - For chemical, physical, and radiological purposes, analyze at least once a year a batch from a representative sample from a continuous production run. The representative sample should consist of the primary containers.

    - Analyze such samples by methods approved by the government agency or agencies having jurisdiction.
- All records regarding regulations in this part shall be maintained for no less than two years.
    - All required documents must be available for official review at reasonable times.

APPENDIX F: FDA Regulation Evaluation (CFR Part 165 – Beverages)

- Bottling of water must comply with applicable regulations in part 129 of this chapter.
- Water must meet requirements to have "sterile water", and they already should be meeting these requirements.
- Bottled water from a community system must contain one of the two following labels:
  - "from a community water system"
  - "from a municipal source"

- Ingredients of the bottled water shall be declared on label as required by part 101.
- Bottled water must contain an amount of substances which is under a set of maximum values. The table is attached in Appendix G.
- The latter section of part 165.110 deals with the testing of all substances being regulated.
- If the water is of substandard quality by containing more of a substance than allowed the water must be labeled with, "Excessively _______" or "Contains excessive _______"
- Water is considered adulterated if it contains any amount of substance that would make the water injurious for human consumption.

APPENDIX G: IBWA Model Code Monitoring Requirements

MONITORING PARAMETER GROUP / *Individual Group Analytes*	MONITORING FREQUENCY	SOQs, MCLs, SMCLs, and Guidelines (Apply to finished products)		
Inorganic Chemicals (IOCs)	ANNUALLY	**IBWA SOQ**	**FDA SOQ**	**EPA MCL**
Antimony (1)	(Product and Source) For items with footnote (2), see *FDA D/DBP Rule Monitoring Requirements on page 21.*	0.006	0.006	0.006
Arsenic		0.01	0.05	0.05
Barium		1	2	2
Beryllium (1)		0.004	0.004	0.004
Bromate (2)		0.010	0.010	0.010
Cadmium		0.005	0.005	0.005
Chlorine (2)		0.1	4.0	4.0
Chloramine (2)		4.0	4.0	4.0
Chlorine dioxide (2)		0.8	0.8	0.8
Chlorite (2)		1.0	1.0	1.0
Chromium		0.05	0.1	0.1
Cyanide (1)		0.1	0.1	0.2
Fluoride		(3)	(3)	4
Lead		0.005	0.005	0.015 AL
Mercury		0.001	0.002	0.002
Nickel (1)		0.1	0.1	
Nitrate-N		10	10	10
Nitrite-N		1	1	1
Total Nitrate + Nitrite		10	10	10
Selenium		0.01	0.05	0.05
Thallium (1)		0.002	0.002	0.002
Secondary Inorganic Parameters	ANNUALLY	**IBWA SOQ**	**FDA SOQ**	**SMCL (4)**
Aluminum	(Product and Source)	0.2	0.2	0.2
Chloride (5)		250	250	250
Copper		1	1	1
Iron (5)		0.3	0.3	0.3
Manganese (5)		0.05	0.05	0.05
Silver		0.025	0.1	0.1
Sulfate (5)		250	250	250
Total Dissolved Solids (TDS) (5)		500	500	500
Zinc (5)		5	5	5
Volatile Organic Chemicals (VOCs)	ANNUALLY	**IBWA SOQ**	**FDA SOQ**	**EPA MCL**
1,1,1-Trichloroethane	(Product and Source) For items with footnote (2), see *FDA D/DBP Rule Monitoring Requirements on page 21.*	0.03	0.2	0.2
1,1,2-Trichloroethane		0.003	0.005	0.005
1,1-Dichloroethylene		0.002	0.007	0.007
1,2,4-Trichlorobenzene		0.009	0.07	0.07
1,2-Dichloroethane		0.002	0.005	0.005
1,2-Dichloropropane		0.005	0.005	0.005
Benzene		0.001	0.005	0.005
Carbon tetrachloride		0.005	0.005	0.005
cis-1,2-Dichloroethylene		0.07	0.07	0.07
trans-1,2-Dichloroethylene		0.1	0.1	0.1
Ethylbenzene		0.7	0.7	0.7
Methylene chloride (Dichloromethane)		0.003	0.005	0.005
Monochlorobenzene		0.05	0.1	0.1
o-Dichlorobenzene		0.6	0.6	0.6
p-Dichlorobenzene		0.075	0.075	0.075
Haloacetic Acids (HAA5) (2)		0.06	0.06	0.06
Styrene		0.1	0.1	0.1

(1) Included in FDA's 9 contaminant regulations.
(2) Included in FDA's D/DBP rule. See D/DBP monitoring requirements section on page 21 in Appendix A for details.
(3) SOQ dependent upon temperature and other factors. See fluoride section on page 22 of Appendix A for details.
(4) SMCL = Secondary maximum contaminant level. SMCLs are guidelines established by the USEPA for use in evaluating aesthetic, non-health-related properties in water. SMCLs are not enforceable for public water systems.
(5) Mineral water is exempt from allowable level. The exemptions are aesthetically based allowable levels and do not relate to a health concern.

All SOQs, MCLs, SMCLs, and guidelines in mg/L (ppm) except as noted. Refer to your state bottled water regulations to determine if additional testing is required.

MONITORING PARAMETER GROUP *Individual Group Analytes*	MONITORING FREQUENCY	SOQs, MCLs, SMCLs, and Guidelines (Apply to finished products)		
Volatile Organic Chemicals (VOCs) (Continued)	ANNUALLY	**IBWA SOQ**	**FDA SOQ**	**EPA MCL**
Tetrachloroethylene	(Product and Source)	0.001	0.005	0.005
Toluene		1	1	1
Trichloroethylene	For items with footnote (2), see *FDA D/DBP Rule Monitoring Requirements on page 21.*	0.001	0.005	0.005
Vinyl chloride		0.002	0.002	0.002
Xylenes (total)		1	10	10
Bromodichloromethane		(6)	(6)	(6)
Chlorodibromomethane		(6)	(6)	(6)
Chloroform		(6)	(6)	(6)
Bromoform		(6)	(6)	(6)
Total Trihalomethanes (2)		0.01	0.08	0.08
Semivolatile Organic Chemicals (SVOCs)	ANNUALLY	**IBWA SOQ**	**FDA SOQ**	**EPA MCL**
Benzo(a)pyrene	(Product and Source)	0.0002	0.0002	0.0002
Di(2-ethyhexyl)adipate		0.4	0.4	0.4
Di(2-ethyhexyl)phthalate		0.006	NA	0.006
Hexachlorobenzene		0.001	0.001	0.001
Hexachlorocyclopentadiene		0.05	0.05	0.05
Total Recoverable Phenolics		0.001	0.001	NA
Synthetic Organic Chemicals (SOCs)	ANNUALLY	**IBWA SOQ**	**FDA SOQ**	**EPA MCL**
2,4,5-TP (Silvex)	(Product and Source)	0.01	0.05	0.05
2,4-D (Dichlorophenoxy acetic acid)	(unless otherwise noted)	0.07	0.07	0.07
Alachlor		0.002	0.002	0.002
Aldicarb		0.003	NA	0.003
Aldicarb sulfone		0.003	NA	0.003
Aldicarb sulfoxide		0.004	NA	0.004
Atrazine		0.003	0.003	0.003
Carbofuran		0.04	0.04	0.04
Chlordane		0.002	0.002	0.002
Dalapon		0.2	0.2	0.2
Dibromochloropropane (DBCP)		0.0002	0.0002	0.0002
Dinoseb		0.007	0.007	0.007
Dioxin (2,3,7,8-Tetrachlorodibenzo-p-dioxin) (1)(7)	Product: Every 3 years Source: Annually	$3x10^{-8}$	$3x10^{-8}$	$3x10^{-8}$
Diquat (1)(7)		0.02	0.02	0.02
Endothall (1)(7)		0.1	0.1	0.1
Endrin	ANNUALLY	0.002	0.002	0.002
Ethylene dibromide	(Product and Source)	0.00005	0.00005	0.00005
Glyphosate (1)(7)	Product: Every 3 years Source: Annually	0.7	0.7	0.7
Heptachlor	ANNUALLY	0.0004	0.0004	0.0004
Heptachlor epoxide	(Product and Source)	0.0002	0.0002	0.0002
Lindane		0.0002	0.0002	0.0002
Methoxychlor		0.04	0.04	0.04
Oxamyl (vydate)		0.2	0.2	0.2
Pentachlorophenol		0.001	0.001	0.001
Picloram		0.5	0.5	0.5
Polychlorinated biphenyls (PCBs)		0.0005	0.0005	0.0005
Simazine		0.004	0.004	0.004
Toxaphene		0.003	0.003	0.003

(1) Included in FDA's 9 contaminant regulations.
(2) Included in FDA's D/DBP Rule. See D/DBP monitoring requirements section in Appendix A for details.
(6) No SOQs or MCLs established for individual trihalomethane contaminants. The sum of the 4 THMs is regulated as total trihalomethanes (TTHMs).
(7) FDA requires that the four synthetic organic chemicals (SOC) listed must be tested quarterly for four consecutive quarters for each type of finished bottled water (e.g., spring, purified, etc.). If none of the SOCs are detected, then once every three years for each type of finished product. If SOCs are detected, maintain monitoring for four consecutive quarters in each three-year period. New products and new companies must do an initial round of quarterly monitoring in the first year of operation.

All SOQs, MCLs, SMCLs, and guidelines in mg/L (ppm) except as noted. Refer to your state bottled water regulations to determine if additional testing is required.

MONITORING PARAMETER GROUP *Individual Group Analytes*	MONITORING FREQUENCY	SOQs, MCLs, SMCLs, and Guidelines (Apply to finished products)		
Additional Regulated Contaminants	ANNUALLY	**IBWA SOQ**	**FDA SOQ**	**EPA MCL**
Methyl tertiary butyl ether (MTBE)	(Product and Source)	0.07	NA	NA
Naphthalene		0.3	NA	NA
1,1,2,2-Tetrachloroethane		0.001	NA	NA
Microbiological Contaminants		**IBWA SOQ**	**FDA SOQ**	**EPA MCL**
Total coliform / *E. coli*	SOURCE: at least once each week (21 CFR §129.35(a)(3)) PRODUCT: at least once each week (21 CFR §129.35(g)(1))	No *Eschericia coli* detectable in a 100 ml portion/sample. No validated total coliform detectable in a 100 ml portion/sample as substantiated by resampling. NOTE: Confirmation AND validation of all positive total colifrm results in finished product required. See Appendix C of the Model Code.	<u>MPN:</u> <2.2 organisms per 100 ml. <u>MF:</u> <4 CFU per 100 ml.	No more than 5% of monthly samples valid for total coliform.
Radiological Contaminants	SEE BELOW	**IBWA SOQ**	**FDA SOQ**	**EPA MCL**
Gross Alpha Particle Radioactivity	SOURCE: Every 4 years	15 pCi/L	15 pCi/L	15 pCi/L
Gross Beta Particle and Photon Radioactivity (8)	PRODUCT: Annually	50 pCi/L	50 pCi/L	50 pCi/L
Radium 226/228 (combined)	SOURCE: Every 4 years PRODUCT: Annually	5 pCi/L	5 pCi/L	5 pCi/L
Uranium	SOURCE: Every 4 years PRODUCT: Annually	0.030	0.030	0.030
Water Properties	ANNUALLY	**IBWA SOQ**	**FDA SOQ**	**GUIDELINE**
Color	(Product and Source)	5 Units	15 Units	5 Units
Turbidity		0.5 NTU	5.0 NTU	0.5 NTU
'pH (9)		5-7/6.5-8.5	NA	6.5-8.5
Odor		3 T.O.N.	3 T.O.N.	3 T.O.N.

(8) If the gross beta particle activity exceeds 50 pCi/1, an analysis of the sample must be performed to identify the major radioactive constituents present. Compliance (with § 141.16) may be assumed without further analysis if the average annual concentration of gross beta particle activity is less than 50 pCi/1 and if the average annual concentrations of tritium and strontium–90 are less than those listed in table A, *Provided,* That if both radionuclides are present the sum of their annual dose equivalents to bone marrow shall not exceed 4 millirem/year. Consult with your testing laboratory for more information.

(9) The Model Code guideline for pH in purified water is 5.0-7.0 (see Appendix B for definition and requirements for purified water). The guideline for source water and other product waters is 6.5-8.5. NOTE: This guideline is not enforceable.

All SOQs, MCLs, SMCLs, and guidelines in mg/L(ppm) except as noted. Refer to your state bottled water regulations to determine if additional testing is required.

FDA D/DBP Rule Monitoring Requirements

Public Water System (PWS) Source Water

If current PWS D/DBP data is available, no source water analysis is required.

If current PWS D/DBP data is NOT available, ANNUAL testing for the following is required:

- Disinfectants: Chlorine, Chloramine, Chlorine dioxide
- Disinfection Byproducts: Bromate, Chlorite, Haloacetic acids (HAA5), and Total Trihalomethanes (TTHMs)

Natural Water Sources

If no disinfection is applied at the source, including use in bulk water hauling, no source water analysis is required.

If disinfection is applied at the source, including use in bulk water hauling, ANNUAL testing for the following is required:

- The residual disinfectant used (chlorine, chloramine, or chlorine dioxide)
- Ozone: Bromate, Haloacetic acids (HAA5), Total Trihalomethanes (TTHMs)
- Chlorine-based disinfectants (chlorine, chloramine, or chlorine dioxide): Haloacetic acids (HAA5) and Total Trihalomethanes (TTHMs)

ALL FINISHED PRODUCTS

ANNUAL testing is required for ALL of the following in each finished product type:

- Chlorine
- Chloramine
- Chlorine dioxide
- Bromate
- Chlorite
- Haloacetic acids (HAA5)
- Total Trihalomethanes (TTHMs)

FDA Requirements for Fluoride in Bottled Water

Bottled water packaged in the United States to which no fluoride is added shall not contain fluoride in excess of the levels in Table 1 and these levels shall be based on the annual average of maximum daily air temperatures at the location where the bottled water is sold at retail.

TABLE 1

*Annual average of maximum daily air temperatures (°F)	Fluoride concentration in milligrams per liter
53.7 and below	2.4
53.8–58.3	2.2
58.4–63.8	2.0
63.9–70.6	1.8
70.7–79.2	1.6
79.3–90.5	1.4

Imported bottled water to which no fluoride is added shall not contain fluoride in excess of 1.4 milligrams per liter.

Bottled water packaged in the United States to which fluoride is added shall not contain fluoride in excess of levels in Table 2 and these levels shall be based on the annual average of maximum daily air temperatures at the location where the bottled water is sold at retail.

TABLE 2

*Annual average of maximum daily air temperatures (°F)	Fluoride concentration in milligrams per liter
53.7 and below	1.7
53.8–58.3	1.5
58.4–63.8	1.3
63.9–70.6	1.2
70.7–79.2	1.0
79.3–90.5	0.8

Imported bottled water to which fluoride is added shall not contain fluoride in excess of 0.8 milligram per liter.

APPENDIX H: Cost Analysis of Bagged Water

PRASA already owns four bagged water machines, Argenpack 2500® machines that produce 2,500 one liter bags per hour. These machines were purchased for $77,700.00. While these machines have already been absorbed by the budget of previous years, PRASA would in fact need to purchase additional machines in order to implement this system. In fact, four more machines would be required produce enough water to serve the deficient areas on a daily basis while still producing excess to store for emergency purposes.

Each machine produces 2,500 bags per hour, or 20,000 bags per day. Four machines combined produce 80,000 bags per day in optimal circumstances. Considering that each family, or client, would receive 20 bags per day if their water service is interrupted, these four machines would server 4,000 people per day. This would just meet the approximate daily need without any option for storage. Also, if any one of the four machines breaks, it will not be possible to produce the daily maximum until that machine is repaired.

In addition to the machines, water, electricity, and plastic are needed to make the packages of water. The Argenpack 2500 ® machines require 1.5kW of power each to operate. Industrial customers of the Puerto Rican Electricity and Power Authority (PREPA) pay between $0.093 and $0.15 per kWh (Martinez, 2001). $0.15 per kWh is used in this analysis since it will be considered the most conservative value. Using this value, operating one machine for one work day, or eight hours, would cost $1.80. To operate one for an entire working year, 260 days, would cost $468.00 in electricity. Now, four of these machines operating simultaneously for one work year would cost four times this value or $1,872.00.

Using the same number of working hours in a day and work days in a year, we can calculate value of the water that will be bagged by these machines. Since each machine can produce 20,000 one-liter bags per day, four machines would produce 20,800,000 one-liter bags of water per year. Based on the estimated rates of PRASA, one liter of water costs $0.00048268 so 20,800,000 liters of water would cost the company $10,039.82. While this cost is not an actual cost, but rather a cost of opportunity in that the water could be sold to clients, but it is instead being used for this bagged water system.

When the machines make a bag of water, it creates the bag from a continuous roll of plastic. Unfortunately, these rolls of plastic are not free. Each roll costs approximately $20.00, depending upon the thickness of the polyethylene plastic, and each machine uses approximately one roll per hour. At this rate, one year's supply of plastic film for four machines would cost $166,400.00.

Lastly, the best form of packaging these bags is through a reusable container. 330 gallon containers cost $473.20 from Freund Containers. These containers could hold approximately 1245 bags of water and 32 would be required per machine. Since these crates could be reused, only an initial investment of $60,569.60 would be required to support four machines operating.

Once all these factors were determined, we have placed everything into a spreadsheet to sum together the costs of each piece of our puzzle. This was also performed for a varying number of scenarios with from one to four bags machines. Table 3 shows the total cost analysis worksheet for the bagged water system.

1 Machine	Year 1			Year 2		
Item	per unit cost	qty	total	per unit cost	qty	total
Argenpack 2500®:	$19,425.00	0	$0.00	$19,425.00	0	$0.00
Maintenance & Parts Inventory:	$4,856.25	1	$4,856.25	$4,856.25	1	$4,856.25
Staffing - Operator	$40,000.00	1	$40,000.00	$40,000.00	1	$40,000.00
Staffing - Labor	$10,712.00	1	$10,712.00	$10,712.00	1	$10,712.00
Plastic Rolls	$20.00	2,080	$41,600.00	$20.00	0	$0.00
Crates	$473.20	32	$15,142.40	$473.20	32	$15,142.40
Labels	$0.02	5,200,000	$78,000.00	$0.02	5,200,000	$78,000.00
Water**:	$0.00	5,200,000	$2,509.96	$0.00	5,200,000	$2,509.96
Electricity for Machines:	$0.15	3,120	$468.00	$0.15	0	$0.00
		Yearly Total:	$193,288.61		Yearly Total:	$151,220.61
		Cost per Bag of Water	$0.04		Cost per Bag of Water	$0.03

2 Machine	Year 1			Year 1		
Item	per unit cost	qty	total	per unit cost	qty	total
Argenpack 2500®:	$19,425.00	0	$0.00	$19,425.00	0	$0.00
Maintenance & Parts Inventory:	$4,856.25	2	$9,712.50	$4,856.25	2	$9,712.50
Staffing - Operator	$40,000.00	2	$80,000.00	$40,000.00	2	$80,000.00
Staffing - Labor	$10,712.00	2	$21,424.00	$10,712.00	2	$21,424.00
Plastic Rolls	$20.00	4,160	$83,200.00	$20.00	4,160	$83,200.00
Crates	$473.20	64	$30,284.80	$473.20	64	$30,284.80
Labels	$0.02	10,400,000	$156,000.00	$0.02	10,400,000	$156,000.00
Water**:	$0.00	10,400,000	$5,019.91	$0.00	10,400,000	$5,019.91
Electricity for Machines:	$0.15	6,240	$936.00	$0.15	0	$0.00
		Yearly Total:	$386,577.21		Yearly Total:	$385,641.21
		Cost per Bag of Water	$0.04		Cost per Bag of Water	$0.04

3 Machine	Year 1			Year 1		
Item	per unit cost	qty	total	per unit cost	qty	total
Argenpack 2500®:	$19,425.00	0	$0.00	$19,425.00	0	$0.00
Maintenance & Parts Inventory:	$4,856.25	3	$14,568.75	$4,856.25	3	$14,568.75
Staffing - Operator	$40,000.00	3	$120,000.00	$40,000.00	3	$120,000.00
Staffing - Labor	$10,712.00	3	$32,136.00	$10,712.00	3	$32,136.00
Plastic Rolls	$20.00	6,240	$124,800.00	$20.00	6,240	$124,800.00
Crates	$473.20	96	$45,427.20	$473.20	0	$0.00
Labels	$0.02	15,600,000	$234,000.00	$0.02	15,600,000	$234,000.00
Water**:	$0.00	15,600,000	$7,529.87	$0.00	15,600,000	$7,529.87
Electricity for Machines:	$0.15	9,360	$1,404.00	$0.15	0	$0.00

Item	per unit cost	qty	total	per unit cost	qty	total
		Yearly Total:	$579,865.82		Yearly Total:	$533,034.62
		Cost per Bag of Water	$0.04		Cost per Bag of Water	$0.03

4 Machine	Year 1			Year 1		
Item	per unit cost	qty	total	per unit cost	qty	total
Argenpack 2500®:	$19,425.00	0	$0.00	$19,425.00	0	$0.00
Maintenance & Parts Inventory:	$4,856.25	4	$19,425.00	$4,856.25	4	$19,425.00
Staffing - Operator	$40,000.00	4	$160,000.00	$40,000.00	4	$160,000.00
Staffing - Labor	$10,712.00	4	$42,848.00	$10,712.00	4	$42,848.00
Plastic Rolls	$20.00	8,320	$166,400.00	$20.00	8,320	$166,400.00
Crates	$473.20	128	$60,569.60	$473.20	0	$0.00
Labels	$0.02	20,800,000	$312,000.00	$0.02	20,800,000	$312,000.00
Water**:	$0.00	20,800,000	$10,039.82	$0.00	20,800,000	$10,039.82
Electricity for Machines:	$0.15	12,480	$1,872.00	$0.15	0	$0.00
		Yearly Total:	$773,154.42		Yearly Total:	$710,712.82
		Cost per Bag of Water	$0.04		Cost per Bag of Water	$0.03

*1 year = 8 hour per day operation of 1 machine 260 days per year
**Cost of Opportunity (price per liter)

Argenpack 2500®: Bagging Machine
Electrical consumption of Argenpack 2500®: 1.5 kW
Operator: Engineers Salary (estimated) - $40,000.00
Labor: Minimum Wage in Puerto Rico $5.15 http://www.dol.gov/esa/minwage/america.htm
Maximum Output of Machines: 2,500 1-Liter bags per machine per hour

Table 3 – Cost Analysis of Bagged Water

APPENDIX I: Cost Analysis of Bottled Water

In order for PRASA to start using a bottled water system, they will need to purchase equipment that can bottle water. Bottles are needed in order to bottles water. There are two options for obtaining bottles. The bottles can be made or they can be purchased from a distributor.

In order to make bottles, a PET blow mold machine will be required. There are two blow mold machines that will be described in this document. First there is the KBA2500, which is distributed by KenPlas. The second machine is the MG-S2500, which is distributed by Meg Machinery. Both of these machines are PET blow mold machines and can produce approximately 2500 bottles per hour. Both of these machines are also fully automatic and only require human intervention to add more preforms into the loader, to remove the completed bottles or to make any repairs to the device.

KenPlas offers the KBA2500 which will produce up to 2,500 bottles per hour. The machine costs $40,100. This is just the base machine, in order to make the machine operate properly; there are extra air compressors and air purification systems that must be purchased as well. You can see the full details of the price quote in Appendix J. The total price of this machine, including one one-liter mold, would come to $54,500. This unit would also consume 63.79 kW of power.

The Molds for he KBA2500 have four cavities, which means they produce four bottles in one cycle. Each of these molds costs $2,900 each; however, each mold can be used for many production cycles.

Mega Machinery offers the MG-S2500 which also produces up to 2500 bottles per hour and consumes 23kW of power. The total system including air compressors and one mold and all accessories is $49,010. This includes a two cavity mold which costs $1,200. More detailed information regarding the machine price quote can be seen in Appendix K.

One item of consideration is that the mold for this device only has two cavities. In order to produce 2,500 bottles, the same two cavities are used twice as much as with the KBA2500 machine's mold. The molds for the MG-S2500 would presumably wear out or break twice as fast, so a new mold would need to be purchased twice as often. However the price of the MG-S2500 mold is less than half the price of the four cavity mold for the KBA2500. Even if two of the two cavity molds are needed in a year, the cost would only be $2,400. While a four cavity blow mold costs roughly $2,900. The two cavity mold would yield a savings of $500 over the four cavity mold. Table 4 shows the details of these two machines side by side.

Company	**Machine Name**	**Machine Price (Total Package)**	**Power Consumed (kW)**	**Number of Cavities per Mold**	**Price of Mold**
KenPlas	KBA2500	$54,500	63.79 kW	4	$2,900
Mega Machinery	MG-S2500	$49,010	23 kW	2	$1,200

Table 4 – Detailed Machine Comparison

Another thing to consider is the Power consumption of these devices. The KenPlas KBA2500 consumes 63.79 kW of power while the Mega Machinery MG-S2500 only consumes 23 kW of power. Industrial customers of the Puerto Rican Electricity and Power Authority (PREPA) pay between $0.093 and $0.15 per kWh (Martinez, 2001).

$0.15 per kWh is used in this analysis since it will be considered the most conservative value. If the cost of electricity is $0.15 per kWh, then multiplying the amount of power consumed (in kW) by $0.15 gives the cost of electricity per hour. Assuming the machines are in operation for 8 hours per day, we simply need to multiply this number by the power consumption of each machine to determine how much the machine will cost per day. Next, assuming there is a 260 day work year, we can multiply this figure times the number of days in a work year in order to estimate the electricity costs for a fiscal year. Table 5 shows the electricity rate comparison for these two machines.

Machine	**Power Consumption (kW)**	**Electricity Rate ($/kWh)**	**Hours Per Day**	**Daily Rate**	**Work Days per Year**	**Yearly Rate**
KBA2500	63.79 kW	$0.15	8	$76.548	260	$19,902.48
MG-S2500	23 kW	$0.15	8	$27.60	260	$7,176.00

Table 5 – Electricity Rate Comparison

In order to make the bottles themselves, a preform is needed. 18g preforms, which are used for making 500ml bottles, can be purchased for $37.80 per 1,000 preforms from KenPlas and $33.75 per 1,000 preforms from Mega Machinery. 28g preforms, which would be used for one-liter bottles, can be purchased for $58.80 per 1,000 preforms from KenPlas and $52.50 per 1,000 preforms from Mega Machinery. Mega Machinery also has the plastic injection mold machinery which is available to create the preforms themselves, as do a number of other distributors; however we will not discuss in any detail in this report on the cost of these machines. Table 6 shows the preform costs in a tabular format.

Company	**500ml preforms (price per 1000)**	**1 liter preforms (price per 1000)**
KenPlas	$37.80	$58.80
Mega Machinery	$33.75	$52.50

Table 6 – Preform Costs

Both of these PET machines are advertised as producing 2,500 bottles per hour. Given that there are 8 hours in a working day and 260 working days in a year, this means that one machine has the potential output of 5,200,000 bottles per year. Including the rates of the preforms and electricity as shown above, as well as the cost of the machines being absorbed into the first year, we can estimate how much it will cost to make each bottle individually for the first year. This can also be done for the second, and any consecutive years, however the prices of the machines will not be included. A maintenance value should be held to keep in mind that it is possible and likely that these machines will at some point require repair. Table 7 shows the calculations the whole package for both brands of PET machine. Notice that in the price per bottle decreases by one cent after the first year.

	Year 1		Year 2*	
Machine:	KBA2500	MG-S2500	KBA2500	MG-S2500
Initial Machine Investment:	$54,500.00	$49,010.00	$0.00	$0.00
Maintenance Costs**:	$13,625.00	$12,252.50	$13,625.00	$12,252.50
Electricity for Machine:	$19,902.48	$7,176.00	$19,902.48	$7,176.00
One Year Supply of 1L Preform:	$305,760.00	$273,000.00	$305,760.00	$273,000.00

Yearly Total:	$393,787.48	$341,438.50	$339,287.48	$292,428.50
Cost per bottle:	$0.0757284	$0.0656613	$0.0652476	$0.0562363
*Each consecutive year should be similar to year 2				
**Maintenance Charges based on possibility of requiring a new mold				

Table 7 – Calculated Production Cost per bottle

Bottles may also be purchased from a distributor. This method is significantly more expensive. Through a visit to the Manantiel del Valenciano bottling company in Las Piedras, we were able to determine that an empty, sterile, one gallon bottle costs $0.23 even when ordered in bulk. Since PRASA is not in the business of making bottles, the following cost analysis will focus on bottles purchased from a third party company.

Filling, labeling, capping, and packaging the bottles are each other issues entirely. In order to fill the bottles, an additionally piece of equipment is required. One such piece of equipment is the VP-50 from Venus Packaging. This machine will fill approximately 2500 bottles per hour; this was chosen intentionally to match the MG-S2500 and the KBA2500. The cost of this machine is $42,000.00 and it utilizes 20HP of electricity, or 14.9139974 kW. At the same estimated electricity rate of $0.15/kWh, this puts the electricity cost at $31021.11 for one year.

Now, the water that goes in the bottle, while PRASA may not pay for it explicitly, PRASA still loses the opportunity to sell that water to a customer. This cost of opportunity still needs to be factored into the cost of the completed bottle of water. After calculating the per liter cost of water to a normal commercial customer to be $0.000483 per liter, we can calculate how much it would cost for one year's worth of potential production. Since one machine could potentially produce 5,200,000 bottles of water in a year, the total cost of water to fill all of these bottles would be $2,509.96.

While the VP-50 filling machine, cleans, fills, and caps the bottles, it does not supply the caps. The bottle caps themselves also do not come with the preforms; they must either be purchased or created with a plastic injection mold process. This report will not outline the cost of the plastic injection. Our meeting with the owner of Manantiel del Valenciano quoted the cost of bottle caps as $0.02 per bottle cap. When purchasing 5,200,000, this means a total cap cost of $1,0400,000.00.

As outlined by the FDA regulations and discussed in previous sections, the bottles themselves must have some sort of label with the appropriate nutrition information as well as a number of other regulatory markings. After meeting with the owner of Manantiel del Valenciano, we determined that labels of this type will cost $0.015. For a purchase of 5,200,000, the labels will generate a cost of $780,000.00.

Once all factors were determined, we created the following spreadsheet for the bottled water machines and totaled all the required costs as shown in Table 8. The total cost for the first year with one machine is $1,492,213.22. Dividing this by the number of bottles that are produced by the machinery for that year yields a cost of $0.28696 per bottle. For the second year, the purchase of the machinery would not be required, however maintenance costs should still be factored in just as in year one. This yields a year two total of $1,450,213.22 or a cost of $0.27889 per bottle. Multiple scenarios are displayed in Table 8 with the possibility of one to four bottling machines.

1 Machine	Year 1			Year 2		
Item	per unit cost	Qty	total	per unit cost	qty	total
Cost of VP-50	$42,000.0000	1	$42,000.00	$42,000.00	0	$0.00
Maintenance & Parts Inventory:	$12,000.0000	1	$12,000.00	$12,000.00	1	$12,000.00
Staffing - Operator:	$40,000.0000	1	$40,000.00	$40,000.00	1	$40,000.00
Staffing - Labor:	$10,712.0000	1	$10,712.00	$10,712.00	1	$10,712.00
Bottles	$0.230000000	5,200,000	$1,196,000.00	$0.23000000	5,200,000	$1,196,000.00

Caps:	$0.020000000	5,200,000	$104,000.00	$0.02000000	5,200,000	$104,000.00
Labels:	$0.015000000	5,200,000	$78,000.00	$0.01500000	5,200,000	$78,000.00
Water**:	$0.001827157	5,200,000	$9,501.22	$0.00182716	5,200,000	$9,501.22
Electricity for Machines:	$0.1500000000	31021.114	$4,653.17	$0.15000000	31021.114	$4,653.17
		Yearly Total:	$1,496,866.38		Yearly Total:	$1,454,866.38
		Cost per Bottle of Water:	$0.28786		Cost per Bottle of Water:	$0.27978

2 Machines	Year 1			Year 2		
Item	per unit cost	Qty	total	per unit cost	qty	total
Cost of VP-50	$42,000.0000	2	$84,000.00	$42,000.00	0	$0.00
Maintenance & Parts Inventory:	$12,000.0000	2	$24,000.00	$12,000.00	2	$24,000.00
Staffing - Operator:	$40,000.0000	2	$80,000.00	$40,000.00	2	$80,000.00
Staffing - Labor:	$10,712.0000	2	$21,424.00	$10,712.00	2	$21,424.00
Bottles	$0.230000000	10,400,000	$2,392,000.00	$0.23000000	10,400,000	$2,392,000.00
Caps:	$0.020000000	10,400,000	$208,000.00	$0.02000000	10,400,000	$208,000.00
Labels:	$0.015000000	10,400,000	$156,000.00	$0.01500000	10,400,000	$156,000.00
Water**:	$0.001827157	10,400,000	$19,002.43	$0.00182716	10,400,000	$19,002.43
Electricity for Machines:	$0.1500000000	62042.228	$9,306.33	$0.15000000	62042.228	$9,306.33
		Yearly Total:	$2,993,732.77		Yearly Total:	$2,909,732.77
		Cost per Bottle of Water:	$0.28786		Cost per Bottle of Water:	$0.27978

3 Machines	Year 1			Year 2		
Item	per unit cost	Qty	total	per unit cost	qty	total
Cost of VP-50	$42,000.0000	3	$126,000.00	$42,000.00	0	$0.00
Maintenance & Parts Inventory:	$12,000.0000	3	$36,000.00	$12,000.00	3	$36,000.00
Staffing - Operator:	$40,000.0000	3	$120,000.00	$40,000.00	3	$120,000.00
Staffing - Labor:	$10,712.0000	3	$32,136.00	$10,712.00	3	$32,136.00
1 Gallon Bottles	$0.230000000	15,600,000	$3,588,000.00	$0.23000000	15,600,000	$3,588,000.00
Caps:	$0.020000000	15,600,000	$312,000.00	$0.02000000	15,600,000	$312,000.00
Labels:	$0.015000000	15,600,000	$234,000.00	$0.01500000	15,600,000	$234,000.00
Water**:	$0.001827157	15,600,000	$28,503.65	$0.00182716	15,600,000	$28,503.65
Electricity for Machines:	$0.1500000000	93063.343	$13,959.50	$0.15000000	93063.343	$13,959.50
		Yearly Total:	$4,490,599.15		Yearly Total:	$4,364,599.15
		Cost per Bottle of Water:	$0.28786		Cost per Bottle of Water:	$0.27978

4 Machines	Year 1			Year 2		
Item	per unit cost	Qty	total	per unit cost	qty	total
Cost of VP-50	$42,000.0000	4	$168,000.00	$42,000.00	0	$0.00
Maintenance & Parts Inventory:	$12,000.0000	4	$48,000.00	$12,000.00	4	$48,000.00
Staffing - Operator:	$40,000.0000	4	$160,000.00	$40,000.00	4	$160,000.00
Staffing - Labor:	$10,712.0000	4	$42,848.00	$10,712.00	4	$42,848.00
1 Gallon Bottles	$0.230000000	20,800,000	$4,784,000.00	$0.23000000	20,800,000	$4,784,000.00
Caps:	$0.020000000	20,800,000	$416,000.00	$0.02000000	20,800,000	$416,000.00
Labels:	$0.015000000	20,800,000	$312,000.00	$0.01500000	20,800,000	$312,000.00
Water**:	$0.001827157	20,800,000	$38,004.87	$0.00182716	20,800,000	$38,004.87
Electricity for Machines:	$0.1500000000	124084.46	$18,612.67	$0.15000000	124084.46	$18,612.67

		Yearly Total:	$5,987,465.54		Yearly Total:	$5,819,465.54
		Cost per Bottle of Water:	$0.28786		Cost per Bottle of Water:	$0.27978

*1 year = 8 hour per day operation of 1 machine 260 days per year
**Cost of Opportunity (price per liter)

VP-50: Automatic Bottling machine
Electrical consumption of VP-50: 14.9139972 kW
Operator: Engineers Salary (estimated)
Labor:Minimum Wage in Puerto Rico http://www.dol.gov/esa/minwage/america.htm
Maximum Output of Machines: 2500 per machine per hour

Table 8 – One Gallon Bottled Water Cost Analysis Worksheet

In the case of implementing one liter bottles of water and creating your own bottles, Table 9 shows the costs and distribution of those costs. The per bottle price is greatly reduced by manufacturing the bottles, however it is another manufacturing step.

1 Machine	Year 1			Year 2		
Item	per unit cost	qty	total	per unit cost	qty	total
Cost of MG-S2500	$49,010.000	1	$49,010.00	$49,010.00	0	$0.00
Cost of VP-50	$42,000.0000	1	$42,000.00	$42,000.00	0	$0.00
Maintenance & Parts Inventory:	$12,000.0000	1	$12,000.00	$12,000.00	1	$12,000.00
Staffing - Operator:	$40,000.0000	1	$40,000.00	$40,000.00	1	$40,000.00
Staffing - Labor:	$10,712.0000	1	$10,712.00	$10,712.00	1	$10,712.00
1 Liter Preforms	$0.05250	5,200,000	$273,000.00	$0.05250000	5,200,000	$273,000.00
Caps:	$0.020000000	5,200,000	$104,000.00	$0.02000000	5,200,000	$104,000.00
Labels:	$0.015000000	5,200,000	$78,000.00	$0.01500000	5,200,000	$78,000.00
Water**:	$0.00048268	5,200,000	$2,509.96	$0.00048268	5,200,000	$2,509.96
Electricity for Machines:	$0.1500000000	99661.115	$14,949.17	$0.15000000	99661.115	$14,949.17
		Yearly Total:	$626,181.12		Yearly Total:	$535,171.12
		Cost per Bottle of Water:	$0.12042		Cost per Bottle of Water:	$0.10292

2 Machines	Year 1			Year 2		
Item	per unit cost	qty	total	per unit cost	qty	total
Cost of MG-S2500	$49,010.000	2	$98,020.00	$49,010.00	0	$0.00
Cost of VP-50	$42,000.0000	2	$84,000.00	$42,000.00	0	$0.00
Maintenance & Parts Inventory:	$12,000.0000	2	$24,000.00	$12,000.00	2	$24,000.00
Staffing - Operator:	$40,000.0000	2	$80,000.00	$40,000.00	2	$80,000.00
Staffing - Labor:	$10,712.0000	2	$21,424.00	$10,712.00	2	$21,424.00
1 Liter Preforms	$0.05250	10,400,000	$546,000.00	$0.05250000	10,400,000	$546,000.00
Caps:	$0.020000000	10,400,000	$208,000.00	$0.02000000	10,400,000	$208,000.00

Item	per unit cost	qty	total	per unit cost	qty	total
Labels:	$0.015000000	10,400,000	$156,000.00	$0.01500000	10,400,000	$156,000.00
Water**:	$0.00048268	10,400,000	$5,019.91	$0.00048268	10,400,000	$5,019.91
Electricity for Machines:	$0.1500000000	199322.23	$29,898.33	$0.15000000	199322.23	$29,898.33
		Yearly Total:	$1,252,362.25		Yearly Total:	$1,070,342.25
		Cost per Bottle of Water:	$0.12042		Cost per Bottle of Water:	$0.10292

3 Machines	Year 1			Year 2		
Item	per unit cost	qty	total	per unit cost	qty	total
Cost of MG-S2500	$49,010.000	3	$147,030.00	$49,010.00	0	$0.00
Cost of VP-50	$42,000.0000	3	$126,000.00	$42,000.00	0	$0.00
Maintenance & Parts Inventory:	$12,000.0000	3	$36,000.00	$12,000.00	3	$36,000.00
Staffing - Operator:	$40,000.0000	3	$120,000.00	$40,000.00	3	$120,000.00
Staffing - Labor:	$10,712.0000	3	$32,136.00	$10,712.00	3	$32,136.00
1 Liter Preforms	$0.05250	15,600,000	$819,000.00	$0.05250000	15,600,000	$819,000.00
Caps:	$0.020000000	15,600,000	$312,000.00	$0.02000000	15,600,000	$312,000.00
Labels:	$0.015000000	15,600,000	$234,000.00	$0.01500000	15,600,000	$234,000.00
Water**:	$0.00048268	15,600,000	$7,529.87	$0.00048268	15,600,000	$7,529.87
Electricity for Machines:	$0.1500000000	298983.34	$44,847.50	$0.15000000	298983.34	$44,847.50
		Yearly Total:	$1,878,543.37		Yearly Total:	$1,605,513.37
		Cost per Bottle of Water:	$0.12042		Cost per Bottle of Water:	$0.10292

4 Machines	Year 1			Year 2		
Item	per unit cost	qty	total	per unit cost	qty	total
Cost of MG-S2500	$49,010.000	4	$196,040.00	$49,010.00	0	$0.00
Cost of VP-50	$42,000.0000	4	$168,000.00	$42,000.00	0	$0.00
Maintenance & Parts Inventory:	$12,000.0000	4	$48,000.00	$12,000.00	4	$48,000.00
Staffing - Operator:	$40,000.0000	4	$160,000.00	$40,000.00	4	$160,000.00
Staffing - Labor:	$10,712.0000	4	$42,848.00	$10,712.00	4	$42,848.00
1 Liter Preforms	$0.05250	20,800,000	$1,092,000.00	$0.05250000	20,800,000	$1,092,000.00
Caps:	$0.020000000	20,800,000	$416,000.00	$0.02000000	20,800,000	$416,000.00
Labels:	$0.015000000	20,800,000	$312,000.00	$0.01500000	20,800,000	$312,000.00
Water**:	$0.00048268	20,800,000	$10,039.82	$0.00048268	20,800,000	$10,039.82
Electricity for Machines:	$0.1500000000	398644.46	$59,796.67	$0.15000000	398644.46	$59,796.67
		Yearly Total:	$2,504,724.49		Yearly Total:	$2,140,684.49
		Cost per Bottle of Water:	$0.12042		Cost per Bottle of Water:	$0.10292

*1 year = 8 hour per day operation of 1 machine 260 days per year
**Cost of Opportunity (price per liter)

MS-S2500: PET Blow Mold Machine
Electrical consumption of VP-50: 14.9139972 kW
VP-50: Automatic Bottling machine
Electrical consumption of MG-S2500: 33 kW
Operator: Engineers Salary (estimated)
Labor:Minimum Wage in Puerto Rico http://www.dol.gov/esa/minwage/america.htm
Maximum Output of Machines: 2500 per machine per hour

Table 9 – One Liter Bottled Water Cost Analysis Worksheet

APPENDIX J: Price Quote for KBA2500 PET Blow Mold Machine

Kenplas Industry Ltd.

Add: 42 Dongjiangwan, Sandun, Hangzhou 310030, China
Tel: +86-571-88943856 Fax: +86-571-88943859

Date ______
No. ______

Quotation List

To M/S: ______
Address: ______

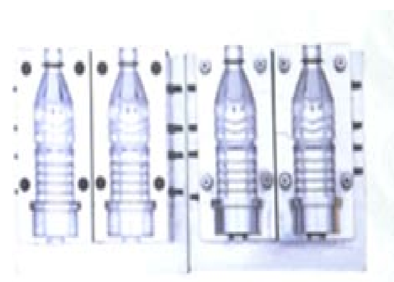
1. Shipment Date: **Within 60 days after receipt of T/T advance.**
2. Packing: Pallets & Wooden Cases
3. Payment Term: [X] 30% T/T advance as deposit, balance 70% by L/C at sight.
4. Insurance: [X] To be effected by the buyers.
5. Remark: Warranty : One year. See Warranty Policy >>
   Spare Parts : Standard spares included. See Spare List >>
   Installation : Buyer bears air tickets & accomodation. See Installation Policy >>

Item	Name of Commodity & Specification		Quantity	Unit Price	Amount	Power (Kw)
				FOB Shanghai		
	Main Equipment					
1	Auto PET Blow Molding Machine	Specification >>				
	(Maximum Bottle Volume: 1.5L)					
	model KBA2500, with air-saving device		1 SET	US$40,100.00	US$40,100.00	28.00 Kw
2	PET Blow Mold	Specification >>				
	0.5L 4 Cavity	2300BPH	1 SET	US$2,900.00	US$2,900.00	
	1.0L 4 Cavity	2100BPH	1 SET	US$2,900.00	US$2,900.00	
	1.5L 4 Cavity	1900BPH	1 SET	US$2,900.00	US$2,900.00	
	Auxillary Equipment					
3	Air Compressor	Specification >>				
	model KAC2.0-40		1 SET	US$6,300.00	US$6,300.00	30 Kw
	(Size of air compressor depends on bottle volume seriously)					
4	Air Purifier	Specification >>				
	(To clean water, oil & dust in the air from air compressor)					
	model KAP2-40		1 SET	US$5,200.00	US$5,200.00	0.11 Kw
5	Water Chiller	Specification >>				
	(To supply cooling water for blow mold and preform neck cooling)					
	model KCA05		1 SET	US$3,000.00	US$3,000.00	5.68 Kw
		TOTAL:	6	AMOUNT:	US$60,300.00	

APPENDIX K: Price Quote for MG-S2500 PET Blow Mold Machine

Here is the production line of MG-S2500 automatic bottle blowing machine, which consists of the MG-S2500 automatic bottle blowing machine and the bottle mold, together with auxiliary machine------air compressor, air filter, air tank, air dryer, ect.

MG-S2500 automatic bottle blowing machine



MG-S2500Automatic Stretch blow Molding Machine & bottle mold

Auxiliary machine for bottle blowing

High pressure air Compressor　Air dryer　Air receiving tank　Low pressure air compressor

Air filter

(1) Air compressor is the air source for PET stretch blow molding machine, carrying out the process of compressing air from atmosphere to the required pressure.
(2) Air dryer is to remove the moisture from the compressed air and lower temperature of the compressed air in the heat exchanger.
(3) Air filter is to clear up the impurities out of the compressed air, like carbon-hydrogen, tiny dust and solid particles.

(4) Air tank is to receive and supply air for the machine as storage.

QUOTATION FOR MG-S2500 PRODUCTION LINE

Item	Description	Type	Unit	Unit price (USD)	Total amount (USD)	Capacity
01	Automatic blowing machine (2-cavity)	MG-S2500	1set	40,000.00	40,000.000	2500b/hr
02	High pressure air compressor		3sets	1200.00	3,600.00	$0.63M^3$/30bar
03	Low pressure air compressor	W1.0-12.5	1set	1000.00	1,000.00	1.0 M^3/12.5bar
04	Air filter		1set	70.00	210.00	
05	Air dryer	RDH-011	1set	1000.00	1,000.00	2.0 M^3/30bar
06	Air receiving tank (high pressure)		1set	1000.00	1,000.00	30bar
07	Water chiller 5HP		1set	1000.00	1,000.00	
08	Bottle mould for 1L	2-cavity	1set	1200.00	1,200.00	
FOB Ningbo port				Total amount: USD 49,010.00		

Main technical specification of MG-S2500 Automatic Stretch Blow Molding Machine

Volume of product	0.1-2.5L
Product raw material	PET
Mould plate maximum dimension	420×500mm
Mould opening stroke	0.1-2L:150mm 6L(1caivty):250mm
Max mould thickness	0.1-2L:150mm 5L(1caivty):250mm
Clamping force	380KN
Air pressure for working	0.8-1.25Mpa
Air pressure for blowing	1.5-4.0Mpa
Temperature control	7 section
Length of pre-form	50-220mm

Inner diameter of pre-form tube	15-126mm
Stretching bar diameter	8-50mm
Quantity of heating rotation	34-60pcs
Length of bottle	340mm
Diameter of bottle	60-220mm
Power	23KW
Temperature in the pre-form	3.5KW
weight	2600kgs
Main machine dimensions (L×W×H)	316×225×226cm
Weight of conveyer	400KGS
Conveyer dimensions	200×190×226cm
Electric voltage/Frequency	220V/380/50Hz

Pneumatic parts for MG-S2500 machine

NO	ITEM	IMPORTED FORM
01	Main cylinder for Clamping	FESTO/Germany
02	Stretching Cylinder	FESTO/Germany
03	Solenoid valve for High pressure 2pcs	FESTO/Germany
04	Solenoid valve for Low pressure 2pcs	FESTO/Germany
05	PLC Controller	TIANJING
06	Water divide	SMC/JAPAN
07	Oil divide	SMC/JAPAN
08	Lubrication	Automatic
09	Temperature controller	It is special design form China famous company
10	Blow pipe	China it can bear 80kgs, actually we only use 30kgs.

APPENDIX L: Interview with David Gilmartin

• Personal interview that took place on February 3rd, 2006 at the Massachusetts Water Resource Authority (MWRA) offices.

Transcribed by Roman Walsh

JR—Josh Rodden

RW—Roman Walsh

DG—David Gilmartin

JR: What is your emergency water distribution plan?

DG: We have two main reservoirs that we use, two storage reservoirs that we use. One is 412 billion gallons and the other one is 63 billion gallons. They are connected to each other by one pipeline, but all water has to transfer through the Wachusett reservoir from the Quabbin reservoir before going to Boston. If there were a transmission problem at the Quabbin aqueduct we could still run off the Wachusett until we fixed it. After that then it gets a little complicated. There are two aqueducts that come off the reservoir in Clinton and also an open channel. Keep that in the back of your head because that's part of the backup plan.

There are many things that can cause an outage of the primary water distribution system. If there's a problem in any one part of it we have work-arounds and enough of the systems so we can have back ups. A problem that would cause us to go to an absolute back up plan would be contamination at the output of Clinton, massive failure of one or both aqueducts, or a third would be a problem with the water treatment plant in Marlboro.

If that were to happen we would rely on a backup system which parts of which were built in 1841. There are four backup reservoirs that weren't used since 1980 and they were only used for a week. And some of this is an open channel we would not be able to use…you see when you talk of distributing bottled water that's only part of the problem. Think of the sewer system and what water is used for. Making electricity, fire fighting, hospitals. We have developed evacuation plans and are able to activate the old aqueducts but we don't know how long we would be able to use that for. And there would be a boiled water order. In this case we would be able to activate the Sudbury system and the Sudbury system consists of a fairly large reservoir that was built in 1895, there's a distribution reservoir built near Boston College that was built in 1869 and an aqueduct that was built in 1869 that we are rehabbing right now for emergency use only. This would also necessitate us sending out what we term mobile disinfectant units. These are trailers that we would put over water sources and have a chlorine drip and we would adjust it and monitor it but people would still have to boil their water.

RW: How would this work? Would you call the Massachusetts National Guard to assist or would the MWRA handle it on its own?

DG: We are able to do this on our own. The Mass Guard, I don't know how well this applies to your work in Puerto Rico but you might want to check this out, there is a water purification unit in the Mass Guard. Its very limited as to the amount of water they can purify but they can set up units at a lake or pond but they have mobile apparatus and can purify a lot of water each day. But with this your looking at distributing in small neighborhoods with water buffalos and that would be chaotic. It might work with a small town such as auburn but the 16 man Massachusetts Guard would have almost no effect if there were a major water shortage. We support around 2.5 million residents not counting businesses and commuters. They don't have enough man power to help in a crisis.

DG: As far as bottled water goes…

RW: So you're saying that you would never use bottled water as a backup system?

DG: You know why? It's because it just wouldn't do anything for us. Our big problem if the system fails is fire fighting water more then anything else. Not all fire fighting systems know how to draft from an open water system. You could pump from the ocean but then you'd need a bronze pump, and I don't even know who has a bronze pump these days. As far as tankers and things like that we don't even have those planned because they wouldn't make sense for us.

RW: And is that because you already have a thorough backup system already planned?

DG: We have a backup system but I don't even know what you would find if you went other places such as Worcester. I don't know what you would find. They have an intake in Route 70 in Boylston. They tried to fire it up one day as a test but the pump broke because it hadn't been used since the Eisenhower administration. But I'm not even going to get into that, I just wouldn't use bottled water. But here's another thing. We're a wholesaler. We purify the water and bring it to the town, but then it's up to the town to distribute it locally amongst the citizens. We contract directly to a municipality. We are in charge of the large pipes going into a town, but all the smaller pipes are the property of the municipality.

JR: In the case of a water shortage how much water would you say the average person needs per day?

DG: We estimate that the average family of four will go through 90,000 gallons of water per year. Now those figures, we just pull them out of a hat. If you have two teenage girls your figure is going to be a hell of a lot higher. Now everyone's will be different but I'd say the minimum amount would be a quarter of that. The minimum amount they would use. But that is just a household, that doesn't take into an account all the business that use water such as food processing plant, a hospital, a utility, a school. If a school has 700 kids they're going to use a lot of water. A nursing home, they use a lot of water. It depends on the community.

JR: It will also depend on the climate because it will be much hotter in Puerto Rico.

DG: Well you would be surprised at how much suburban communities who are largely residential will use. All the houses are 5,000 sq ft houses and the water sprinkler system will suck up a lot of water.

RW: So you'd say that less water would be used in an urban environment?

DG: Absolutely, absolutely.

RW: Would you consider yourself a benchmark, in the, I don't want to say industry, but compared to other water distribution systems such as in New York or Seattle?

DG: We each have our own, we have different… ours is the closest to New York. Seattle has different threats that they respond to. See one of the things they do in Seattle is that they have trailers with flexible pipes on them that they have all over the place. In the case of an earthquake they just bring the flexible pipes and put them on the surface. I think ours has the only site activation team. We are probably a lot further ahead on the critical infrastructure in terms of video surveillance, and entry alarms, and general security. I don't have any way of knowing because I haven't been to a conference in years. In terms of big systems, New York just spent a hundred million dollars, Cleveland just spent a lot of money, but I don't think many are as far advanced as we are.

(He showed us the plans for what would happen in different cases of emergencies)

DG: There are consulting firms that are just happy to take your money.

JR: Two French firms were working with PRASA in Puerto Rico, Suez, and Vivendi.

DG: They have been trying to buy up water systems in the US. They bought a few in Atlanta. The experience is pretty bad. They skimp on capital. Sorry, I mean they make things that we would consider operational costs, capital costs. So at the end of the 5 year contract, your billed for 5 million dollars but you still have to do all this work on the system. A plan is only as good as its late update.

Shortly after this the tape ran out. The interview lasted roughly another 15 minutes and then he showed us the control room and how emergencies would be operated. Additional topics, subjects and recommendations will be listed below.

- Without water being pumped through to an area the sewage will become stagnant. Rain water enters into the system through storm drains but without this additional water the sewage will become septic.
- The Bioterrorism Act of 2002 made backup plans mandatory in case of a contamination or destruction of the system. This is helpful for systems all over the country because it applies to areas of non-terrorism such as leaks or accidental contamination.

- In case of a contamination will water be bottled in advance? Also the same holds true for a power outage. A generator might be needed.
- The EPA doesn’t regulate bottled water the Department of Agriculture does, specifically the FDA.
- The Adjunct General of Puerto Rico might have information on whether or not the Puerto Rican guard has a water purification team.
- David said that if he would have to implement a bottled water system he would outsource it to Poland Springs, or Coca-cola so as to not deal with all the red tape the FDA would bring. The additional risks for distributing and contamination weren’t worth it to him.
- He drills his emergency bottled water team in exercises to replicate what might or could happen. He provides very complicated exercises to keep his workers on their toes so they can act in a crisis.
- Smaller bottles would be the best for water distribution because most people can lift a liter of water and bring it back to their homes, but not everyone could lift a three to five gallon jug. Smaller bottles would allow people to take what they need and not any more.

APPENDIX M: Interview with Andres Garcia

• Phone interview that took place on February 7th, 2006.

Transcribed by Josh Rodden

The interview began with each member of the group introducing themselves to Andres Garcia. Andres then introduced himself along with two of his coworkers who will be helping us on the project.

YC – Yaralia Castillo

BF – Bryan Ferguson

RW – Roman Walsh

JR – Josh Rodden

AG – Andres Garcia (Secretary of Water Needs to the President)

M – Mayra (Director of Emergency Department)

AG: We are a public corporation. We are 100% a government entity. We have 1.3 million clients, and are probably the complex utility in the Northern hemisphere. In terms of number of systems, we have 131 filtration plants, 60 wastewater treatment plants, 1600 pump station, and 1.3 million clients. We serve drinking water to all of those clients. In the past four years there were some experiments by the government to administer the operations with a private contractor. That, for reasons we don't need to discuss today, did not work out. So the government decided in 2004 to return the operation and administration back to the government's hands. So that is where we are now. We have a new revised law that was approved in 2004 and basically now Puerto Rico is divided into five regions; the north, south, east, west, and metropolitan regions. Each region is divided into operational areas. In each region are one or more municipalities within the island. In October of last year we went through an increase in water rates for the drinking water service. It was a significant increase. We went about 68% – 75% over the previous water rates. We have further steps to increase it even more on July 1st, of this year. So we are in the process of revising that final step. Obviously, by charging more for services and needs, we are getting more pressure, people expect more from us, more people are writing letters, asking for better service and more efficiency. That is basically where we are right now.

Regarding this project, in 2003 or 2004, the last private industry, which administered PRASA, purchased four machines to produce packages of water. They were purchased to provide drinking water to clients during emergency situations or while a community has no service due to construction or whatever. Each machine is about eight feet tall and about three feet wide. Those machines produce, per unit, 1.5 liters each into small plastic bags. We haven't used these machines. They weren't bought by us. They were bought by a private contractor. If we were going to buy machines for this use today, we would buy different machines. The reason is that those plastic bags produced by the machine are common to South America, but not in Puerto Rico. We are not use to plastic bags of water. In the U.S. we are used to bottles of water.

So we have the machines and want to use them wisely. We have to develop a proper plan. We need to produce and package the water. Distribute the water and perhaps to store it, that is something to decide. We also need to define the target. Why and where to do that. Meaning if we have the machines in San Juan, and there is a necessity on Mayaguez on the other side of the island two hours from San Juan, how and when do we start distribution? How and when we decide how many packages we would want to send? Previous to the emergency or based on information we have. So this is the issue we are talking about.

Also, for your information, we have issued a decree that we want to evaluate if it would be beneficial for PRASA to get into the bottled water market. We want to try and sell bottled water like any other private company. It would be water produced by different machines, which we haven't purchased yet. I just wanted to make that quick comment to separate them. We are not talking about bottled water to sell here. We are talking about packages of water to provide to communities in specific situations. Emergency situations specifically, where there is a real necessity, because that requires production, distribution, storage and all that.

RW: Has there been any research done related to the water distribution problem?

AG: In regards to the machines?

RW: Yes

AG: No, there has not. Our job has been to provide water to our clients and infrastructure. To distribute bottled water and packaged water is a new area for us. Basically, all we have are the machines. We have them connected with water and electricity.

M – says some information in Spanish that Andres relays to us.

AG: Let me add on to Mayra here. We have to decide if we want to compete with the private sector in terms of selling water through grocery stores and all that. This is just for your information, but is not part of this project. To add to this project, we want to decide if we need to purchase more machines. They would be different machines, more robust and with greater capacity. This could complement what we have now, to develop a more efficient process. Again, we have these four machines, which produce packaged water. We are looking into new machines, which produce bottled water that would increase more efficiency in terms of distribution. I hoped this answered your question.

RW: Are the facilities supplying the water already set up? You mentioned that the machines were connected with water and power.

AG: Yes, they are not facilities, specifically they are machines. They are in Guaynabo, which is close to San Juan. They are hooked up to the facilities in a filtration plant. A small portion of the water from this filtration plant goes to these machines.

RW: How much water would the average person need in a day in the case of a water emergency?

AG: The average family consumption would be around 100 gallons per day. In terms of an emergency, we provide water only for terms of drinking and cooking. Not water that is to be used for bathing. For just water consumption we are talking about two to three gallons a day. With cooking you could survive with around five gallons a day.

RW: Would an urban or rural environment need more water, Such as San Juan compared to a rural town?

AG: San Juan obviously has a much greater population. Its water needs will be much greater. However, you can have a large community and a rural community that have the same amount of customers. So it just really depends.

YC: Also, will the water also be servicing other places such as hospitals and emergency rooms?

AG: That is part of the analysis, which you have to do.

YC: Right now, are these types of facilities your clients?

AG: We provide to every commercial and industrial company. They are all our customers.

RW: What additional costs will the new distribution system bring?

AG: That question is for you to answer.

RW – Roman and Andres talk about the wording of a question so that Andres can better understand the question. Roman asks Andres how important the cost is within this project?

AG: Definitely the cost is very important and that is to part of your analysis. But again, we want to know how much it will cost for different scenarios. For example, do you want to do the Cadillac? This will be the cost and scope. Or do you want to do the pinto. We have a little smaller scope and this will be the cost. So our expectations are to have different scenarios for different situations.

RW: What is the source of water for the packaged water?

AG: It is water that goes out from the filtration plant, to my house for example. It is intercepted at the machinery and placed into a plastic bag. I would like you to research if we need to apply an additional treatment to the water. Right now, we basically provide a disinfection process to our water using chlorine. The question is whether we need additional treatment to water, which will be stored in a plastic bag.

RW: We have already done some information. The Federal Drug Administration regulates bottled water. One thing they said is that as long as water comes from tap, as long as it meets EPA standards, then you can bypass further processing. The plants are checked once a year, and as long as it passes EPA regulations, it passes FDA regulations.

AG: That is very important for us. First, because of the health and compliance issues. But also it an issue for us. If we have to provide additional treatment to the water that we are already serving to our people, it will be hard to explain this to the common people. Because the initial reaction will be, people will ask whether the water we are serving now needs additional treatment. The answer is of course, no. We have complied with the federal and local regulations. Explaining to one million clients is a different issue. This is a very important question for us to answer. To gain specific relations to regulations and maybe benchmark any cases which we can use as examples.

RW: Certain states have further regulations regarding bottled water. Is this true with Puerto Rico?

AG: That is something that needs more research, and Mayra can help you in your research. She can give you contacts and some of the answers. Basically, Mayra has some contacts that deal with bottled water. Maybe you can visit one of those and see how it works. Possibly asking further questions there.

YC: One more question. How long would you expect service to be interrupted, and the amount of time the machines would be in use over the course of a year?

AG: Basically if there is a problem we don’t use the machines. If there is a hurricane or an issue. Anything we can predict will just depend on the situation. We do know the communities, which have inefficient service. We also know the communities, which have poor access. Also, we have ways to know which communities that will be affected by work on facilities.

YC: Also, for our further research. Do you know the make or model of the machines?

AG: Yes, Mayra will email you more information on the machines. I believe they were made in Argentina. We will send you a copy of some brochures of the machine. The machines produce about 2000 packages per hour. I just read that quickly.

YC: Is there anything else that you would like us to do research on? We are going to continue to do research on answering your questions. Anything else specifically you have in mind?

AG: I think you should base it on what Mayra sends you. Her e-mail is Mayra.encarnacion@acueductospr.com. Mayra and I will send you information on the communities that have problems with service. So you have an idea, we have 70,000 clients who have been deemed to live in communities with common problems with their water service. Daily, we have an average of between 8000 and 20000 clients that have water service problems. It is a combination of things. You can have 12000 clients today without service due to say rainfall in the mountainous regions. Those local communities are affected. On the same day you can a community on the east side of the island, which doesn't have water because we are replacing a pipeline. At the same time you could have a problem on the west side of the island because of power loss.

The interview concluded here.

APPENDIX N: Sponsor Description

Our liaisons in Puerto Rico were Andres Garcia and Mayra Encarnacion of the Puerto Rican Aqueduct and Sewer Authority (PRASA). PRASA is a government run organization which is responsible for providing water to its customers throughout the island. Their mission statement is to "develop, own, and operate all installations and facilities necessary to provide potable water, sewage collection, and treatment services to the people of Puerto Rico." (Clark, 2000) The Puerto Rican water supply is derived from reservoir systems, which from time to time have service interruptions from water main leakages and breaks, contamination, and natural disasters such as hurricanes. It is crucial for the citizens to have access to clean, fresh water during these service interruptions. The goal of this project was to devise an efficient method for packaging, storing and distributing packaged water when needed.

PRASA operates under the laws of Puerto Rico but more generally operates under the US laws governing water quality and safety. The Environmental Protection Agency (EPA) is the proponent water safety in the United States. In the past PRASA has been fined by the EPA for improper sewage discharge into the environment. However, they have also received grants from the EPA to fix their sewage problem. (EPA 2005)

Puerto Rico is divided into five regions of Metro, North, East, West, and South, by PRASA. There are 129 potable water treatment plants which treat 514 million gallons per day and 66 waste water treatment plants which treat 214 million gallons per day. PRASA has over 11,000 miles of water distribution and wastewater pipelines combined. Their 6000 employees use these pipelines to serve their 1.2 million clients. (Puerto Rico Industrial Development Company 2006) While these statistics address most of the island, the remaining population, roughly 100,000 people, get their water from private wells or community based water systems. (Environmental Protection Agency, 2006)

The Puerto Rican Government has tried to improve PRASA by having the government's Infrastructure and Financing Authority restructure PRASA. The government has twice tried to outsource its water management to the large French water firms named Vivendi and Suez. Neither of these firms was highly regarded by the public. More specific information detailing the eight year experiment with privatization can be found in Appendix O.

The Suez owned company named Ondeo is one such company that PRASA outsourced its management to. This company is more familiar with South American cultures where water, oil, milk and many other liquids are sold in plastic bags (Garcia, 2006). The population of Puerto Rico is not used to seeing liquids in bags but rather in bottles, which is common in the United States. Ondeo purchased four machines that place water into one-liter bags in order to attempt to implement an emergency water distribution plan. Ondeo did not have enough time to develop such a plan before the government seized back control of PRASA and as a result these four machines are inactive in two PRASA filtration plants. PRASA owns these machines and would now like to implement them within the emergency management department.

Historically, much of the island has been disappointed in the water management and distribution. Major leaks in the pipeline system and constant lack of water have plagued the island. The government of Puerto Rico has a number of plans to improve the water system by introducing a super aqueduct to San Juan in addition to building more filtration plants. They plan to invest over 1.5 billion dollars into the water system (Puerto Rico Herald, 2005).

PRASA has received a very large budget from the government up until 2005, even though the utility companies have traditionally been independent, at least with regards to finances. Part of the reason PRASA had not become independent is due to the water rates simply being too low. In October 2005, the water rates were significantly increased and further increases are proposed for the summer of 2006. Hopefully with the proposed investments into the water infrastructure, PRASA will be able to appease the public while still increasing revenues in order to become independent of the government.

APPENDIX O: PRASA over the Last Decade

PRASA is Puerto Rico's public service agency that handles fresh water delivery on the island. In the mid-nineties, however, the Roselló administration decided to privatize PRASA and outsource its service to a private company (Public Citizen, 2006). The purpose behind these contracts was to save the Puerto Rican government money. Unfortunately at the end of the eight-year privatization experiment, the government agency was left in a worse situation than before.

Compania de Aqua (Water Company) is a subsidiary of Vivendi and was contracted to handle Puerto Rico's water delivery system in 1995. PRASA hired the Water Company in the hopes that they would be able to help with many of the problems with the infrastructure of PRASA (Public Citizen, 2006). Unfortunately, these hopes may have been ill placed.

Four years after the start of the contract with the Water Company, reports showed that the Water Company still had "deficiencies in the maintenance, repair, administration and operation of aqueducts and sewers." (Public Citizen, 2006) Even after four years under management that was supposed to repair these structural problems, none of these problems were resolved. Even worse, a number of their financial reports were either late or never submitted.

It also appeared during this time that the health of residents who did not have centrally controlled water was actually worsening. "There were higher incidents of skin allergies, gastroenteritis, and muscle spasms from carrying heavy water containers long distances." (Public Citizen, 2006)

“Puerto Ricans complained that Vivendi workers didn’t know where to find aqueducts and valves in need of repair, but that they were always able to find a way to bill their customers for unconsumed water.” (Public Citizen, 2006) The idea that the Water Company was potentially overcharging for water was ironic since PRASA had incurred $241.1 million dollars of debt by 1999 under the new private management.

Unfortunately, additional time did not help the Water Company solve the problems with the infrastructure. “In May of 2001, another report came out charging Vivendi with 3,181 deficiencies in infrastructural administration, operation, and maintenance.” (Public Citizen, 2006) In addition, the operational deficit for PRASA grew to $683 million in only three years and the EPA began to fine PRASA upwards of $6 million for non-compliance with federal U.S. laws.

Even after considering these problems many Puerto Ricans believed that the Water Company had slightly improved PRASA (Cimadevilla, 2004). In 2002, the Calderón administration did not want to validate the water management decision made by the previous administration when there were still so many problems with PRASA. The administration did decide to outsource the water management, but did not renew the contract with the Water Company. Instead, a company named Ondeo was chosen.

In 2002, PRASA signed a contract with a second French-owned company named Ondeo to manage the water distribution systems of Puerto Rico (McPhaul, 2005). While the public opinion of the Water Company may have been low, Ondeo may arguably have been liked less. This contract was intended to last 10 years, however the government terminated the $4 billion contract early.

Over the two-year experience with the Suez owned Ondeo, the company unfortunately did not meet a number of their contractual obligations. (Public Citizen, 2006). The government cited four areas where Ondeo was lacking. First, Ondeo failed to improve access to water in all communities. Ondeo also failed to meet EPA standards, balance the budget and improve the infrastructure of the distribution system. Finally Ondeo asked for an additional $93 million in order to meet the initial contractual obligations.

In 2004, PRASA cancelled its contract with Ondeo with 8 years left and decided to manage the water and sewer systems on its own with the hope that it could bring the organization back on its feet.

Once PRASA took back control of the water and sewer systems, managing the debt left from privatization as well as other management problems proved harder than first imagined. One major issue that the newest incarnation of PRASA faced was dealing with the Independent Authentic Union (UIA) (McPhaul, 2005).

PRASA management first decided to privatize the health plan for union workers (McPhaul, 2005). The UIA decided to respond to this by declaring a strike on October 4th, 2004. PRASA management was able to settle with the UIA about the health plans by allowing a choice of plans. However, the UIA workers did not go back to work until December 27th, 2004 when the economic benefit differences were resolved.

Money still managed to be a large issue for PRASA. The privatization experiment left the organization in with a large operational deficit. Ondeo had made a request for an extra $93 million per year to continue with their operations (Cimadevilla, 2004). After the government complained that Ondeo wanted more money to fulfill its contractual obligations, the chairman of PRASA requested $215 million a year more than the $360 million budgeted. He felt that with this money PRASA would be able to meet the public's demand for water.

When PRASA took back the water and sewer management, it also took over a number of projects that had to be completed in order for the EPA standards to be met (McPhaul, 2005). Some of these projects included the refurbishment of 100 leaking sewage pump stations upstream from water-supply intakes, as well as installing water-filtration systems at 45 plants. The EPA also ordered the implementation of a preventative maintenance plan for every water and sewage facility.

PRASA currently serves 1.3 million customers and considers itself one of the most complex infrastructures in the northern hemisphere (A. Garcia, phone interview, February 7, 2006). PRASA has 131 filtration plants, 60 wastewater treatment plants, and 1600 pump stations. In October 2005, PRASA increased the cost of fresh water for consumers by 68%-75% and plans to significantly increase the rates again in July of 2006. As a result of increased rates, the public is placing a significant amount of pressure on PRASA for better service and efficiency. Some customers have gone as far as writing letters to the organization regarding service and efficiency. The number of these letters has increased with time.

PRASA still has a number of goals to reach in order to reduce their deficit, operating budget and raise the overall image of the organization. It may also be possible that at some point PRASA will be re-privatized, but it that seems unlikely in the immediate future.